ИЗМЕРИТЕЛЬНАЯ ТЕХНИКА

Number 3, March, 1960

Translation Published December, 1960

THE UNIVERSITY OF MICHIGAN

ENGINEERING LIBRARY

SOVIET INSTRUMENTATION AND CONTROL TRANSLATION SERIES

Measurement Techniques

(The Soviet Journal *Izmeritel'naya Tekhnika* in English Translation)

■ This translation of a Soviet journal on instrumentation is published as a service to American science and industry. It is sponsored by the Instrument Society of America under a grant in aid from the National Science Foundation with additional assistance from the National Bureau of Standards.

SOVIET INSTRUMENTATION AND CONTROL TRANSLATION SERIES

Instrument Society of America Executive Board

Dr. Ralph H. Tripp
President
J. Johnston, Jr.
Past President
Philip A. Sprague
President-elect-Secretary
Henry J. Noebels
Dept. Vice President
E. A. Adler
Dept. Vice President
Adelbert Carpenter
Dept. Vice President
Nathan Cohn
Dept. Vice President
Francis S. Hoag
Dept. Vice President-elect
John C. Koch
Treasurer
Nelson Gildersleeve
Dist. I Vice President
H. Kirk Fallin
Dist. II Vice President
John R. Mahoney
Dist. III Vice President
F. R. Gilmer
Dist. IV Vice President
Milton M. McMillen
Dist. V Vice President
Otto J. Lessa
Dist. VI Vice President
J. Howard Park, III
Dist. VII Vice President
Roy Horton
Dist. VIII Vice President
Robert C. Mann
Dist. IX Vice President
Kenneth S. Vriesen
Dist. X Vice President
John J. McDonald
Dist. XI Vice President

Headquarters Office

William H. Kushnick
Executive Director
Charles W. Covey
Editor, ISA Journal
Herbert S. Kindler
Director, Tech. & Educ. Services
Ralph M. Stotsenburg
Director, Promotional Services
Ira S. French
Director, Public Relations

ISA Publications Committee

Charles O. Badgett, *Chairman*

Jere E. Brophy	George A. Larsen	Joshua Stern
Dr. Enoch J. Durbin	Thomas G. MacAnespie	Frank S. Swaney
Prof. Richard W. Jones	John E. Read	Richard A. Terry

Translations Advisory Board of the Publications Committee

Jere E. Brophy, *Chairman*

T. J. Higgins	S. G. Eskin	G. Werbizky

■ This translation of the Soviet Journal *Izmeritel'naya Tekhnika* is published and distributed at nominal subscription rates under a grant in aid to the Instrument Society of America from the National Science Foundation. This translated journal, and others in the Series (see back cover), will enable American scientists and engineers to be informed of work in the fields of instrumentation, measurement techniques, and automatic control reported in the Soviet Union.

The original Russian articles are translated by competent technical personnel. The translations are on a cover-to-cover basis and the Instrument Society of America and its translators propose to translate faithfully all of the scientific material in *Izmeritel'naya Tekhnika*, permitting readers to appraise for themselves the scope status, and importance of the Soviet work. All views expressed in the translated material are intended to be those of the original authors and not those of the translators nor the Instrument Society of America.

Publication of *Izmeritel'naya Tekhnika* in English translation started under the present auspices in August, 1959, with Russian issue No. 1 of Jan.-Feb. 1958. The program has been continued with the translation and printing of the 1959 and 1960 issues which are monthlies.

Transliteration of the names of Russian authors follows the system known as the British Standard. This system has recently achieved wide adoption in the United Kingdom, and is currently being adopted by a large number of scientific journals in the United States.

Readers are invited to submit communications on the quality of the translations and the content of the articles to ISA headquarters. Pertinent correspondence will be published in the "Letters" section of the ISA Journal. Space will also be made available in the ISA Journal for such replies as may be received from Russian authors to comments or questions by American readers.

1960 Volume Subscription Prices:

Per year (12 issues), starting with 1960, No. 1

General: United States and Canada	$25.00
Elsewhere	28.00
Libraries of nonprofit academic institutions:	
United States and Canada	$12.50
Elsewhere	15.50
Single issues to everyone, each	$ 6.00

1958 and 1959 issues also available. Prices upon request.

See back cover for combined subscription to entire Series.

Subscriptions and requests for information on back issues should be addressed to the:

Instrument Society of America
313 Sixth Avenue, Pittsburgh 22, Penna.

Translated and printed by Consultants Bureau Enterprises, Inc.

Copyright 1960 by Instrument Society of America

EDITORIAL BOARD OF IZMERITEL'NAYA TEKHNIKA

G. D. Burdun *(Editor)*
I. I. Chechik *(Asst. Editor)*
V. I. Ermakov
N. M. Karelin
M. I. Levin
G. N. Sharonov
L. M. Zaks
M. K. Zhokhovskii

Measurement Techniques

A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR

Russian Original Dated March, 1960

1960, No. 3, pp 179-270 December, 1960

CONTENTS

	PAGE	RUSS. PAGE
LINEAR MEASUREMENTS		
Complex Checking of Spur Gears in Single-Profile Meshing with a Measuring Screw. M. N. Bokin	179	1
Checking Contact Angles of Radial-Thrust Bearings. N. B. Bruevich and Z. M. Breitman	181	2
Automatic Measurement of Jet-Pump Needle Displacements. M. K. Gavrilenko	183	4
Adjustment and Repairs of Clock-Type Indicators. A. V. Érvais	184	5
MEASUREMENTS OF MASS		
Checking Technique for Motor-Truck Weighbridges. S. I. Gauzer	188	8
Portable Undismountable Scales. I. N. Selezneva and M. V. Petkevich	193	11
MECHANICAL MEASUREMENTS		
Differential Resistance High-Pressure Gauges. M. K. Zhokhovskii and V. V. Bakhvalova	195	12
Calibration of Three-Component Dynamometers. V. F. Paramonov	198	15
ELECTRICAL MEASUREMENTS		
A Semiconductor Source of Standard (Reference) Voltages. Yu. R. Nosov	201	17
Highly Stable DC Voltage Sources for Measuring Circuits. R. F. Kozlov	204	18
Single Slide-Wire Rectangular-Coordinate AC Compensators. L. F. Kulikovskii and A. L. Tsiber	205	19
A Method of Measuring the Loss Angle of Capacitors. M. S. Mikitinskii	209	22
Effect of the Coil Inductance on the Frequency Error of Rectifying Instruments. E. N. Kurilov and M. N. Drogomyzhskaya	212	25
Design of Damping Springs for Torsion-Suspension Instruments. P. I. Khrenkov	219	30
HIGH AND ULTRAHIGH FREQUENCY MEASUREMENTS		
Investigation of a High-Frequency Thermistor Voltage Meter. A. M. Fedorov and B. E. Rabinovich	222	31
An Oscillographic Method of Measuring Frequency Deviation of Frequency-Modulated Signals. P. A. Shpan'on and N. B. Petrov	226	34
RADIATION MEASUREMENTS		
Miniature Radiation Meters with Electric Generators. B. Z. Votlokhin	232	38
A Magnetic Gamma-Spectrometer with an "Annular" Field. A. S. Karamyan and P. T. Prokof'ev	233	39
LIQUID AND GAS FLOW MEASUREMENTS		
Discharge Coefficients of Double Bevel Diaphragms. V. I. Romanenko	237	41
ESSAYS AND REVIEWS		
Digital Electromechanical Voltmeters and Ohmmeters. V. M. Shlyandin	240	45
MATERIAL RECEIVED BY THE EDITORIAL BOARD		
Problems of Organizational and Technical Preparations of Temporary Branches in Rural Areas. V. V. Petropavlovskii	249	50

CONTENTS (continued)

	PAGE	RUSS. PAGE
Increasing Labor Productivity in Inspection Work. E. S. Adaryukov.	251	52
Reviving the Activity of Industrial Laboratories. N. G. Klyuchnikov	253	54
The Necessity of Producing a Reference Book for the Repair and Adjustment of Measuring Instruments. A. N. Andrianov.	255	55
The Problem of Measuring Equipment Repairs Has Been Overlooked. V. N. Shchukin	256	56
INFORMATION		
Conference on Automatic Control and Methods of Electrical Measurement. A. M. Ilyukovich.	257	57
International Conference on the Measurement of Liquid Discharge in Open Channels and Waterways. S. B. Bulatov and N. M. Karelin.	259	59
N. F. Rymar'.	264	61
COMMITTEE OF STANDARDS, MEASURES, AND MEASURING INSTRUMENTS		
Changes in Instructions for Verification of Instruments for Measuring Temperature. N. M. Staroverov.	265	62

COMPLEX CHECKING OF SPUR GEARS IN SINGLE-PROFILE MESHING WITH A MEASURING SCREW

M. N. Bokin

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 1-2, March, 1960

The design of all the instruments used in practice for checking kinematic errors of spur gears in single-profile meshing suffer from a common defect, which consists in comparing the gear under test with a reference gear which also has a kinematic error.

It has been established in practice that the error of standards must not exceed 25-30% of the checked articles' tolerance. Since the reference spur gears cannot be made at present with a higher than 3rd grade accuracy, it is obvious that only gears up to the 5th or even 6th grade accuracy can be checked by means of instruments using reference gears.

Hence the recommendation [1] to check 3rd grade gears by this method cannot be considered as valid.

The checking of precision spur gears (of the 3rd to 5th grade) can only be carried out by the above method if the accuracy of the reference gears is improved.

In addition to the reference gear a measuring screw can also serve as a standard.

Measuring (reference) screws can be made with greater accuracy than reference gears.

Measuring gears are used as standards in the universal instrument for complex double-profile checking of small module gears [2].

In this instrument the kinematic error of the gears is checked in double-profile meshing by the variation of the distance between the centers. The double-profile method does not provide, however, a complete picture of the kinematic error of the gear under tests.

The method suggested by the author for checking the kinematic error of spur gears consists of determining the error in single-profile meshing with a floating measuring screw by the axial displacement of the screw.

The meshing of the measuring screw with the gear under test reproduces the movement of the milling machine hob.

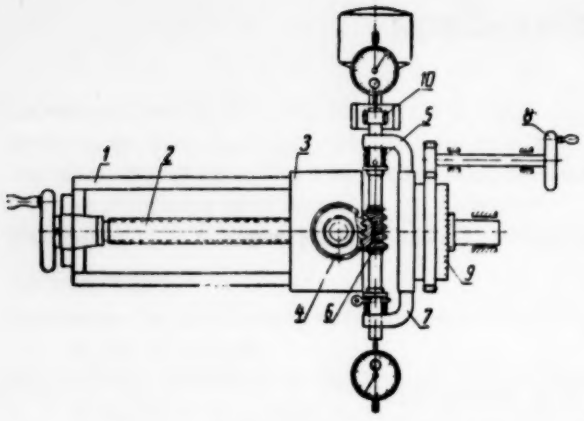
The difference between the two consists in the fact that the measuring screw does not introduce any geometrical errors, whereas such errors are peculiar to the hob, and that the geometrical errors of the gear under test, which the gear obtained when it was cut on the milling machine, are transformed into a kinematic error, compensated by the variations of the side gap, i.e., by the axial displacement of the floating measuring screw.

This checking method corresponds to the essence of the kinematic error as determined by GOST 1643-56, and can be implemented by means of the arrangement whose diagram is shown in the figure.

A moving carriage 3 fixed to a clasp nut is displaced by means of screw 2 along slides 1 of the base.

Carriage 3 carries an expanding mandrel which holds gear 4 under test. A constant resistance moment is produced at the other end of the mandrel spindle and balanced by light springs 5 which press against the spindle of measuring screw 6.

Gear 4 under test is engaged in single-profile meshing with the measuring screw 6.



The screw should be made in such a manner that its normal section profile corresponds to the initial contour of the toothed rack which was used for cutting the gear and its linear pitch is equal to the meshing pitch.

The nominal distance between centers is set either by means of block gauge, or by the main scale and the vernier which are mounted on the instrument base and the carriage.

The spindle of the measuring screw is held in bearings 7 which can be placed by means of geared handwheel 8 at the required angle with respect to the helix angle of the screw and the angle read off the measuring device 9 and the vernier.

Depending on the side of the profile to be checked the measuring screw can be switched by means of spring 5 into the right or left hand position.

The screw is driven by motor 11 either by means of geared or belt transmission.

The speed of rotation of the measuring screw is adjusted by means of a rheostat according to the number of teeth of the gear under test and the number of turns of the screw.

The kinematic error of the gear under test is balanced by the measuring screw displacement which is recorded either on a micrometer, or an induction or photoelectric transducer [4]. In this measurement only one micrometer is operated at a time, depending on which side of the profile is being tested, and the readings of the other one are ignored.

The above method of checking the kinematic error of spur gears in single-profile meshing with a floating measuring screw has the following advantages as compared with the existing methods:

1) the greater precision of measuring screws as compared with reference gears makes it possible to measure gears of any degree of accuracy;

2) the possibility of using the measuring screw for checking gears of any diameter providing they are of the same module.

When this method of measuring gears is used, the kinematic error tolerances given in the tables of GOST 1643-56 should be corrected for the tolerance in the axial displacement of the measuring screw.

LITERATURE CITED

[1] B. A. Taits, Mashinostroitel' No. 1, 1958.

[2] G. N. Filatenko, A Universal Instrument for Complex Double-Profile Checking of Small Module Gears [in Russian] (NTO Mashprom. Leningrad, 1957).

[3] Author's Certificate No. 120011 of March 12, 1959.

[4] M. N. Bokin, Ministry of Higher Education of USSR Bulletin "Instrument Making" No. 3, 1958.

CHECKING CONTACT ANGLES OF RADIAL-THRUST BEARINGS

N. B. Bruevich and Z. M. Breitman

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 2-4, March, 1960

The reliability and life of radial-thrust bearings are determined by a number of parameters, including one of the most important of them, which is the angle of contact.

According to GOST 831-54 the angle of contact is defined as angle β formed by the plane passing through centers of the ball bearings and the line through the points of contact of the balls with the track:

$$\beta=\tan^{-1}0.34\ \frac{Q_A}{Q_R}. \tag{1}$$

where Q_A and Q_R are respectively the maximum axial and radial loads.

Up to the present the contact angles were checked indirectly by measuring the complementary radial clearances and using the following expression:

$$\cos\beta_b=\frac{2R_S-\Delta_b-\frac{Q_b}{2}}{2R_S-\Delta_b} \tag{2}$$

and

$$\cos\beta_S=\frac{2R_b-\Delta_S-\frac{Q_S}{2}}{2R_b-\Delta_S}, \tag{3}$$

where Q is the complementary radial clearance of the bearing; R is the radius of the raceway; Δ is the diameter of the balls; β is the contact angle of the bearing.

The determination of the contact angles by means of these expressions is not sufficiently precise owing to the presence of considerable variations in the dimensions of the raceway radii and the ball diameters.

This problem was only solved by using the relationship between the linear velocities of the ball races and the balls of the bearings, a relationship depending on the angle of contact of the bearing. This original method of checking contact angles was first proposed by Leider in 1951.

During testing, the two ball races are made to revolve in the opposite directions and their angular velocities are so chosen that the balls and cages do not rotate about the axle of the bearings. The conditions for the balls remaining in the same position is the equality of the linear velocities of the internal and the external races:

$$\frac{\pi d_e n_e}{60}=\frac{\pi d_i n_i}{60}, \tag{4}$$

where d_e and d_i are the raceway diameters of the external and the internal races; n_e and n_i are the angular velocities of the external and internal races when the cage remains stationary.

In order to determine the angle of contact let us transform (4):

$$d_e=D_m+d_b\cos\beta \tag{5}$$

and

$$d_i = D_m - d_b \cos\beta, \tag{6}$$

where D_m is the mean diameter of the raceway; d_b is the ball diameter.

After these expressions are substituted in (4) it assumes the form

$$\frac{\pi (Dm + d_b \cos\beta)\, n_e}{60} = \frac{\pi (Dm - d_i \cos\beta)\, n_i}{60}, \tag{7}$$

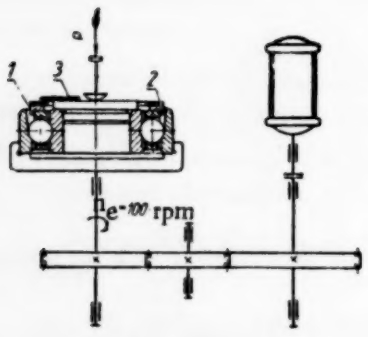
whence

$$\cos\beta = \frac{Dm}{d_b}\left(\frac{n_i - n_e}{n_i + n_e}\right). \tag{8}$$

The contact angle of the bearing in question is equal to

$$\beta = \arccos\left[\frac{D_m}{d_b}\left(\frac{n_i - n_e}{n_i + n_e}\right)\right]. \tag{9}$$

By utilizing this expression it became possible to make measuring devices for direct checking of the contact angle of radial thrust bearings in the following manner.



The races of the bearing under test are made to revolve in opposite directions by means of independent continuously adjustable drives; by changing the angular velocity of one of the races, the cage is brought to a stationary condition; the ratio of the angular velocities of the races under this condition provides a sufficiently accurate measurement of the actual contact angle of the bearing.

However, instruments based on this principle are complicated and not very productive.

In the process of the further development of this method it was decided to determine the contact angle by measuring the angle of rotation of the cage with respect to one of the races which is kept stationary while the other is rotated through a determined angle.

In this instance the linear velocity of the rotating raceway is twice as great as that of the balls on a circumference of a mean diameter.

The expressions by means of which the angles of contact are determined have the following form:

$$X^\circ_{cg} = 180^\circ\left(1 + \frac{d_b \cos\beta}{Dm}\right) \tag{10}$$

when the external race is rotated through 360°, and

$$X^\circ_{cg} = 180^\circ\left(1 - \frac{d_b \cos\beta}{Dm}\right) \tag{11}$$

when the internal race is rotated through 360°.

Thus:

$$\cos\beta = \frac{D_m}{d_b}\left(\frac{\chi'_{cg}}{180^\circ} - 1\right) \tag{12}$$

when the external race is rotated one turn and

$$\cos\beta = \frac{D_m}{d_b}\left(1 - \frac{\chi'_{cg}}{180^\circ}\right) \tag{13}$$

when the internal race is rotated one turn.

By using above expressions it was possible to construct a simpler and at the same time more accurate measuring instrument whose diagram is given in the figure.

The internal race is fixed in a stationary position and takes the axial load of the bearing during measurement. The external race is rotated by means of a motor through a reduction gear and special friction drive in a determined direction through a set number of turns. Scale 2 calibrated in degrees of the contact angle is fixed to the cage of the bearing. For convenience of reading and rejection of faulty bearings, the two limiting values of the contact angle are marked off on the scale. When the external race is rotated through a given angle, the cage with the scale fixed to it also rotates through a definite angle, whose value depends on the contact angle of the bearing.

The contact angle scale is read by means of a fixed pointer 3. The instrument is very simple, convenient in operation and is highly productive in checking. The error of measuring the contact angle by means of this instrument does not exceed 3°.

SUMMARY

On the basis of the above method of measurement, using expression (4), highly productive semiautomatic devices were made for sorting out bearings by their contact angles into three groups: "small," "good" and "large."

The adoption by our industry of these measuring devices for checking the contact angles will raise considerably the quality and life of radial-thrust bearings.

AUTOMATIC MEASUREMENT OF JET-PUMP NEEDLE DISPLACEMENTS

M. K. Gavrilenko

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 4-5, March, 1960

In order to record the jet-pump needle travel of a 2 ChN 240/270 engine we designed and made an inductive transducer, whose principle of operation is based on the change of the impedance of an induction coil owing to the movement of the core which is connected to the needle by means of the needle-spring bushing.

The transducer consists of two coils in a common textolite body 3 (Fig. 1), a needle-spring bushing 2 screwed by means of an M6 thread to the stem of frame 3, and steel core 4 pressed into the lower bushing of the needle spring.

The transducer frame has a through hole which carries at one end a moving core and at the other an M3 × 8 screw (1), intended for balancing the bridge. The lengths of the two coils must be the same and so chosen as to produce a linear relations between the variation of the inductance and the displacement of the needle. For this purpose the ratio of the coil length to the core displacement must be large; in this device it is equal to 25.

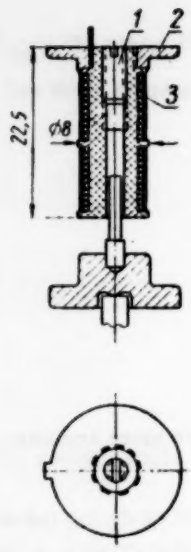


Fig. 1.

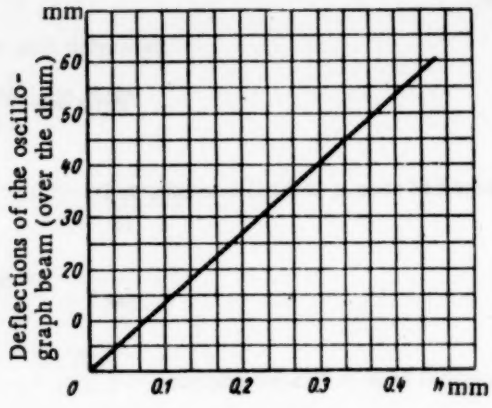


Fig. 2.

A winding of 100 turn of 0.12-0.18 mm enameled wire is wound on the frame, covered with cotton insulation, and glued with adhesive BF-2. The ends of the coil are taken out through grooves in frame 3 and bushing 2.

The placing of both coils under the same temperature conditions eliminates any temperature errors. The inductive transducer is connected in a bridge circuit.

For recording dynamic processes it is necessary that the supply frequency should be 8-10 times higher than that of the phenomena under consideration. On the basis of this consideration the detector-amplifier developed by the V. I. Lenin Khar'kov Polytechnical Institute for the transducer uses a carrier frequency of 100 kc.

The detector-amplifier consist of an AM superheterodyne receiver which detects the bridge unbalance voltages. In this amplifier the output current is proportional to the bridge unbalance (the displacement of the core) in the range of ±120 ma at a load of 3.5 ohms.

Owing to the feeding of the bridge with a high frequency voltage, the amplifier frequency characteristic (the relation of the output current to the bridge signal frequency) has no dip in the range of 0-50 cps, which normally occurs in ac amplifiers, and is linear from 0 to 7 kc. This circumstance makes it possible to calibrate the bridge at static variations of the bridge balance.

Figure 2 shows the calibration of the inductive transducer taken on oscillograph MPO-2 with type one loop at a minimum amplifier gain.

It will be seen from the graph that the sensitivity of the transducer is large and the relation of the output current to the displacement of the core, which is connected to the jet needle, is linear. If the sensitivity is too large for loops of the first type, the output of the amplifier is shunted by means of a suitable resistance selected during calibration.

ADJUSTMENT AND REPAIRS OF CLOCK-TYPE INDICATORS

A. V. Érvais

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 5-7, March, 1960

The extensometer indicator adjustment and repair methods given below apply mainly to indicators of the "Krasnyi Instrumental'shchik" plant, but can be used with a few exceptions for adjusting other types of indicators.

For repairing indicators a set of spares, obtainable at the manufacturing plant, is required; it should include gears, small and large pointers, hair springs, scales with 0.01 and 0.02 mm calibrations, springs, and endpieces.

Scale, pointers, endpiece. If individual markings are damaged on the scale they are restored by painting them over with India ink or the scale is replaced.

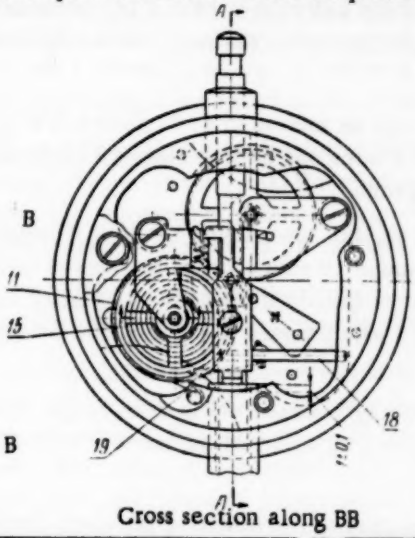
The rotation of the scale by its rim should be smooth; after adjustment the scale should be fixed securely and must not tend to be displaced during operation. The latter property is ensured by means of a wire-spring ring 1 (figure).

The normal effort for turning the rim is attained by adjusting ring 1, which is made accessible by removing clamping ring 2, cover glass 3, ring 4, the large 5 and small 6 pointers and scales 7 and 8.

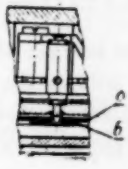
The working surface of the endpiece must be free from all signs of wear, pronounced scratches, etc.

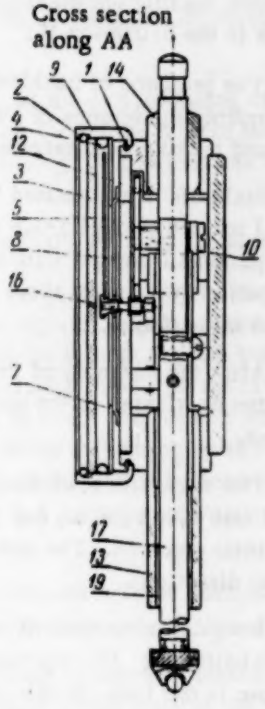
If these defects exist, the endpiece is polished on a table or other type of small lathe. The endpiece is fixed in a collet chuck or its stem is placed in a split bushing (made of copper or aluminum) and then fixed in a jaw chuck. Next an imprint is made on an aluminum plate of approximately 3 × 20 × 100 mm by means of a ball with a radius equal to that of the endpiece. The imprint is successively filled with lapping paste of 30, 10 and 4 μ (for lapping). Microabrasive powders M28, M14 or M5 may be used.

The spherical surface of the endpiece is then lapped in a rocking movement.



Cross section along BB





Tolerances, μ				Variations in readings, μ
Over a range of 1 mm at any part of the scale	Over the entire scale			
	for ranges of			
	0–2 and 0–3 mm	0–5 mm	0–10 mm	
30	30	35	40	5

For checking the position of the large and small pointers rim 9 is turned with the scale in such a manner that the 0 and 50 graduations come approximately in line with the axis of the measuring rod; the large pointer must then be some 20-25 divisions to the left of the axis of symmetry of indicators with a range of 0-5 and 0-10 mm and some 10-15 divisions from the axis of indicators with a range of 0-2 and 0-3 mm. When the large pointer is in the zero position, the small pointer must also be at zero. Deviations from a given position must not exceed ±15 divisions for indicators with a measuring-rod displacement of 1 mm/turn and ±10 divisions for indicators with a displacement of 15 mm/turn.

If these conditions are not fulfilled the small pointer should be removed from its spindle and readjusted according to the position of the large pointer. The small pointer is removed by means of a standard tool used in watchmaking. The large pointer is removed by means of two small screwdrivers placed diametrically opposite to each other under the rim of the pointer.

In fixing the pointers, care should be taken that neither the small nor the large one touch the scale, that the large one does not scrape the cover glass or foul the small pointer. The required position of the pointers is attained by straightening them with tweezers. The large pointer should be approximately 0.7 mm above the scale.

After repeated stopping of the large pointer at the detent, the position of the needle should not change. If the small pointer remains in the zero position and the large one becomes displaced, it shows that pinion 10 has become loose or that the large pointer with its rim is turning on its axle.

If both pointers become displaced, it shows that gear 11 (z = 100) has become loose. If the socket of the large pointer becomes loose, the pointer is removed, the socket compressed and the pointer readjusted in position. This is followed by repeated stopping of the pointers at the detents (some 10-15 times).

Sometimes the reason for the pointer's displacement is bad fixing of the pointer to its socket. It is, therefore, advisable to check the fixing of the pointer to its socket before assembly. If the pointer rocks on its axle, the pointer socket should be center-punched lightly in three or four places.

If the error is due to the pinion turning in the gear to which it is fixed, the gear and pinion should be removed and examined. If the pinion is loose in the gear, the butt end of the former should be center-punched in three-four places and its operation rechecked.

Gear mechanism. When the measuring rod is lowered gently, the pointer should return to its initial position. Its deviation from the original position should not exceed ±0.005 mm and the rod movement should be smooth. The main reasons for this defect are dirt in the gearing or between the rod and sleeves 13 and 14, or corrosion of the latter, insufficient measuring effort, and, mainly, backlash in the gearing due to the lack of tension, or weak tension in the hairspring 15.

The presence of backlash is determined by means of a wedge with an incline of 1: 20 placed in a universal or measuring microscope or by comparing the indicator readings with a telescope caliper mounted on the same stand and making, simultaneously, contact with a flat table or an end gauge.

Backlash is eliminated by increasing the tension of hairspring 15. For this purpose the lock is taken out, gear 11 rotated through 1-1.5 turns and while holding the spindle of pinion 16 with a finger the lock is replaced. When pinion 10 engages with the rack of the measuring rod 17 the pinion spindle is released. By turning the lock by means of two fingers about the spindle the engagement of pinion 10 with the rack is adjusted and the lock secured in the frame.

After the assembly of the mechanism it should work without sticking over the whole of its range. Irregular operation or sticking of the mechanism indicate bad assembly and, mainly, incorrect engagement of pinion 10 with the rack.

The engagement of the pinion with toothed rack of rod 17 is checked in the following manner: the rack is held fast with a finger, and the gear wheel 11 (z = 100) is gently rocked with a screwdriver and the position of the pointer observed. The pointer should then oscillate between the fifth and twelfth divisions of the red scale (reverse direction).

Irregular movement of the measuring rod 17 is due to several reasons: 1) axial play in pinion 10 or gear 11 with hairspring 15; this defect is eliminated by tightening the crossbar; 2) either the stud screws or the studs are loose in the lock; in this case the screws are tightened or the studs are loose in the lock; in this case the screws are tightened or the studs center-punched; 3) the measuring rod is slightly bent; this can be rectified by giving it in situ a gentle blow with a copper hammer; 4) the pointers either touch each other or the scale or the glass cover; this is eliminated by adjusting the pointers with tweezers. Sometimes an irregular movement of the measuring rod is caused by a displaced millimeter scale 8, thus producing friction between the rim of the small pointer socket and the edges of the hole. In this instance the scale should be fixed firmly to its pins. Attention should also be paid to prevent the hairspring touching the frame or components of the mechanism.

If the mechanism is found to be dirty or parts of its corroded (this is easily seen if the indicator is examined with the lid taken off), the mechanism should be washed out with pure benzine, having previously cleaned the corroded parts of the mechanism. Gear teeth are cleaned with a wooden rod covered in lapping paste.

Corrosion and scratches on pivots are cleared by means of a table-type lathe and a burnishing file, used in watchmaking. The rotating surface of the pivot is gently touched by the burnishing file.

After the mechanism is assembled, its pivots and axles are oiled by means of a small screwdriver dipped in watch oil in such a manner that the oil does not flow over the remaining parts of the mechanism.

Measuring rod. Swinging of the measuring rod about its axis is checked by hand at the beginning, middle and end of its travel.

This defect is caused by wear in the dowel pin 18 or the dowel recess. It can be easily cured by replacing the dowel pin.

The radial play of the rod is due to the wear of its smooth part and that of the sleeve's internal diameter.

The radial play is checked by means of a special wire dynamometer (see instruction 141-55) simultaneously with checking its swinging about the axis. Variations in the readings should not exceed 0.5 division of its scale.

If the radial plug is larger than the above tolerance, the defect can be eliminated by replacing bushing 19. Sometimes it is possible to eliminate it by dimensional chromium-plating of the smooth part of measuring rod (the teeth of the rack are isolated from the plating by a special paste). The actual diameter of the sleeve hole is measured beforehand. The rod is chromium-plated so that its diameter is 3-4 μ larger than that of the hole. This is required so that the rod can be lapped in the sleeve successively with 30, 10 and 4 μ lapping powders (in a dry state).

The measuring effort is adjusted by means of spring 19. If the measuring effort is larger than required, only one of the spring turns is slightly stretched out, and if it is smaller the spring is shortened. If a given spring cannot provide, after adjustment, the required effort, it is changed. Springs are made of piano wire 0.2 N-P according to GOST 5047-49. The wire diameter is 0.2 $\pm$0.03 mm, the number of turns is 46, the external diameter of the helix 2.2 mm and the length of the spring with the eye 13.6 mm.

Variations in readings arise due to variations in the position of the pointer along the axis, swinging of the measuring rod (both in the radial direction and about its axis), wear of teeth on pinion 10 and the rack of the measuring rod, looseness of pinion 10 in gear 12, and insufficient tension in the hairspring. Variations due to these reasons are eliminated by the methods described above.

Elimination of measurement errors. The causes of measurement errors are basically the same as those of reading instability; hence the method of eliminating them are similar.

In addition to above repair methods others can be used for indicators with the range of 0-3 mm: the gear wheel with the pinion is turned gradually through 1-2 teeth with respect to one of the rack teeth and the indicator readings are noted at the same time. In order to check the displacement of the gears with respect to the rack they must, obviously, be disengaged. The pinion is rotated until a position is found in which the reading error is at a minimum. By means of this operation it is possible to decrease the error by a value amounting up to 5 μ. If the rotation of the pinion does not produce any effect, it is necessary to change pinion 10; then by increasing or decreasing the tension of the hairspring it will be possible to reduce the error by 1-3 μ. When the error is only slightly larger than the tolerance such adjustment produces satisfactory results.

In the 0-2 mm range indicator the position of the pinion with respect to the rack can only be changed by taking it out of the quadrant and then pressing it back again and center-punching at the base.

The rotation of the pinion in an indicator with a 0-10 mm range does not produce satisfactory results, since all the teeth of its pinion become equally worn. In this case it should be established in which position the maximum error occurs and gear wheel 12 marked with a pencil accordingly. Next the locking gear is taken out and gear wheel 12 is rotated so that the mark comes opposite the beginning of the indicator travel i.e., near its zero reading. The lock is then replaced, the position of pinion 10 with respect to the rack of measuring rod 17 adjusted and checking of the indicator readings continued.

If the indicator is so worn that it is impossible to repair it, the range of its readings can then be reduced. First a portion of the travel is chosen over which the readings are within the specified limits, and the moment of the measuring rod is restricted by pins fixed at appropriate places on the rod.

Indicators which have exceeded, due to wear, the accuracy tolerances specified in GOST 577-53 and cannot be repaired, should be used again with new scales whose, graduations are increased in value (up to 0.02 mm). In this connection new deviations given on page 185 are permissible.

MEASUREMENTS OF MASS

CHECKING TECHNIQUE FOR MOTOR-TRUCK WEIGHBRIDGES

S. I. Gauzer
Translated from Izmeritel'naya Tekhnika, No. 3, pp. 8-11, March, 1960

The problem of the most efficient and accurate method for checking motor-truck weighbridges has not been solved and weighbridges are checked by methods which are not accurate or comparable at the point of dispatch and reception of goods.

In this article the existing method for checking motor-truck weighbridges and certain proposals in this connection are presented for discussion by the readers of this journal.

The checking of these weighbridges is at present carried out only according to the method laid down in instruction 15-52.

This method includes checking at 10% of the maximum load by placing standard weights in the center and at the corners of the weighing platform, and checking at the maximum load by means of standard weights of 20 kg each.

Considering that in the overwhelming majority of cases State inspectors do not possess the required number of standard weights, the instruction permits checking by means of a ballast load.

The ballast-load method consists in balancing the weighbridge by means of 3rd-grade standard weights, whose mass is usually equal to 10% of the maximum load, then replacing the weights by some other load (ballast); next adding the standard weights to the load and replacing them again by a ballast load, etc., until the maximum load is attained.

In addition to this method provided in the instruction some of the State Inspection Laboratories unofficially also use the method of adding a small weight.

According to this method weighbridges which have been checked at 10% of the maximum load are balanced at a load Q_1 (a loaded truck) close to the maximum load Q_{max}, and the first weighing A_1 is noted. Next, standards weights of mass $q = Q_{max}/m$, where m is a coefficient depending on the mass of the available standard weights, is added to the load. The new load is balanced by moving the scale weight and a new reading A_2 is obtained.

The relative error ΔA of the weighbridge is determined by the mass of the added standard weights and the difference of readings S_1-A_2 after the weights of value q have been added to the load:

$$\Delta A = \frac{A_2 - A_1 - q}{qm} = \frac{A_2 - A_1 - q}{Q_{max}}.$$

It is then considered that the accuracy tolerance is:

$$\Delta A_{tol} = \pm \frac{\Delta A_{tol\ max}}{m}.$$

For instance when 1 ton of standard weights is available the checking of weighbridges up to 10 tons is carried out in the following manner.

1. A loaded truck of 8-9 tons is driven unto the weighbridge and balanced.

Let the reading of the weighbridge then be A_1 = 8590.0 kg.

2. Standard weight q = 1000 kg are added to the load. Then m = 10: 1 = 10.

On second balancing the weighbridge reads A_2 = 9589.3 kg.

3. The relative error of the weighbridge is determined from

$$\Delta A = \frac{9589.3 - 8590.0 - 1000}{10000} \cdot 100 = -0.007\%.$$

The weighbridge tolerance is

$$\Delta A_{tol} = \frac{\pm 0.1\%}{10} = \pm 0.01\%.$$

Thus the weighbridge is passed as satisfactory.

The study of weighbridge checking methods showed that weighbridges can only be checked accurately by means of standard weights, and the checking by means of ballast loads and especially small weights does not provide accurate results.

When checking is done by means of ballast loads each substitution of standard weights by a ballast load will produce an error, even with satisfactory sensitivity and stability of readings, due to the difference between the mass of the ballast and that of the standard weights caused by the sum of the reading and variation errors.

According to experiments carried out at the NGIMIP on weighbridges with satisfactory metrological characteristics, when 10 substitutions of loads were carried out, the error amounted to 0.13% thus exceeding tolerance.

If the sensitivity and variations of weighbridges are close to their limiting values of error in the mass of the balast can be exceeded considerably the permissible error, thus making it possible to reject good and pass faulty weighbridges.

The method of checking weighbridges by means of a small weight cannot be considered at all valid since it does not determine the error of the weighbridge, but that of the difference of errors of two very similar loads, a difference which cannot serve as a metrological characteristic of the weighbridge. Moreover this difference can only be determined on weighbridges with a high sensitivity, which is not common even in the best weighbridges.

In this article new methods of checking developed by the VNIIK, the NGIMIP and by I. S. Krever are described.

The VNIIK method consists of checking the weighbridges with 3rd-grade weights in a manner similar to the one recommended in instruction 15-52 with the difference that each weight is of 500 kg instead of 20 kg and the weights are made of a cylindrical shape with two protruding bands for convenience of their rolling along the weighing platform.

These weights are transported in a truck [1] equipped with a crane for their loading and unloading; the truck is also used as a ballast load thus reducing the number of standard weights required for checking.

After the weighbridge has been checked at a load exceeding the weight of the truck, the weights are rolled off the platform and replaced by the truck. Next the weights are added to the load and the maximum weighing capacity checked.

The VNIIK method of checking is the most reliable. Some of its weaknesses should, however, be noted:

1. When the standard weights are replaced by the truck an error is committed which lowers the accuracy of checking.

2. The application of the VNIIK method requires large capital expenditure, and with the maximum load of the weighbridges being raised to 25-50 tons this method will become even more cumbersome and will require even larger capital expenditure.

The NGIMIP method consists in checking weighbridges by means of two lever dynamometers.

For the application of this method it is necessary to construct in addition to the normal brick foundation an additional stone foundation, for anchoring bolts, to which the jacks and dynamometers can be fixed during testing.

The effort produced by the jacks is transmitted simultaneously to the weighing platform and the dynamometers and the measurement error is obtained by comparing the weighbridge reading with that of the dynamometers.

The idea underlying this method is good, since for checking a 10 ton weighbridge it is necessary to transport not more than 1.5 tons of equipment and for a 25 ton bridge some 3.0 tons.

The application of this method, however, is difficult owing to the following reasons.

1. The price of the lever dynamometers is high and they are not reliable in operation, since with the slightest wear in the knife-edge bearings their error exceeds the specified tolerances.

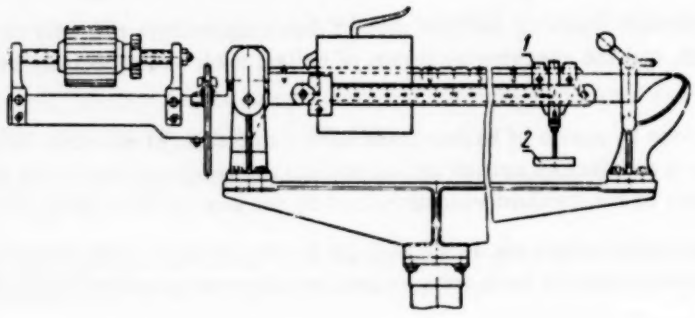


Fig. 1. 1) Carriage; 2) pan for weights.

2. The reliability of this checking is also in doubt, since the weighbridge lever system is restricted and the weighing arm will not be able to follow the normally required smooth damped oscillations – whose absence was observed when an attempt was made to check weighbridges by means of hydraulic dynamometers with unsealed pistons.

3. Additional errors of the NGIMIP method due to inclined jacks and dynamometers, the technique of fixing them, their stiffness, etc., have not been sufficiently studied, but the inevitable accumulation of these errors is obvious from the experience of checking tensile strength testing machines.

4. Another disadvantage of the NGIMIP method is the considerable increase in the cost of the foundations.

When the disadvantages of these methods are taken into consideration, I. S. Krever's method becomes very attractive.

The essence of this method consists in the following operations.

The weighbridge is checked at a 10% load, but the balance arm is checked separately in a machine according to instruction 15-52.

If the sensitivity and variation of the weighbridge readings at a 10% load do not exceed 0.1% (i.e., if it is twice as good as specified) a loaded truck weighing 80-90% of the maximum load is driven at a speed not exceeding 5 km.p.h. over the weighing platform in both directions. The variations of the weighbridge zero readings should not exceed 0.01% of the maximum load.

Next the truck is weighed twice, having been driven onto the platform from either side, and the difference in these two readings must not exceed 0.02% of the mean weight of the truck.

At the same time the sensitivity of the weighbridge is determined by varying the load by 0.05% of the weight of the truck; this variation must produce at least a 5 mm deflection of the moving pointer from the stationary one.

If the weighbridge satisfies all these requirements an aluminum carriage with a pan for weights (Fig. 2) is fixed at the end of the arm (Fig. 1) near the balance indicators and the weighbridge is balanced by means of tare weights.

Next, third-grade standard weights of a total of one ton are placed in the middle of the weighing platform and the weighbridge is balanced by means of second-grade standard weights placed on the weights' pan, thus determining the "value of one ton" P_1, i.e., the mass of second-grade weights which balance 1 ton of third-grade weights placed in the middle of the weighing platform.

Having removed the standard weights from the platform, the truck is driven on to it in such a manner that its rear wheels are placed over the left-hand side knife-edge bearings. The truck is weighed by means of second grade weights placed in the pan of the device and a reading A_1 is obtained.

A total of 1 ton of third grade weights is then placed over the right-hand side knife-edge bearings and a new reading B_1 is obtained.

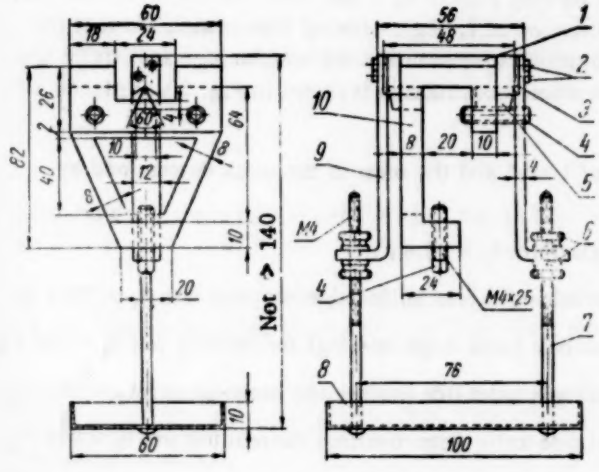


Fig. 2. 1) Cushion; 2) screw; 3) insert; 4) clamping screw; 5) knife-edge bearing; 6) nut; 7) rod; 8) pan for weights; 9) side support; 10) carriage frame.

The truck is then placed on the platform in such a manner that is rear wheels are above the right-hand side knife-edge bearings, the weighbridge is balanced by second-grade weights and reading A_2 is obtained. Another ton of third-grade weights is then placed over the left-hand side knife-edge bearings and yet another reading B_2 is obtained.

The mass of the truck expressed in terms of the mass of standard weights at the pan of the carriage will then be:

$$M_1 = \frac{A_1 + A_2}{2},$$

and the "value of 1 ton" obtained from 2 weighings will be

$$P_2 = B_1 - A_1 \; ; \quad P_3 = B_2 - A_2.$$

The mean "value of 1 ton" P obtained from three readings is

$$P = \frac{P_1 + P_2 + P_3}{3}.$$

The mass of the truck M_C is calculated by dividing the mass of second-grade weights M_1, which balance the weight of the truck, by the "value of 1 ton" P:

$$M_C = \frac{M_1}{P}.$$

Having determined the calculated mass of the truck, the standard weights are removed both from the weighing platform and the pan of the device, and the truck is weighed by means of the sliding weights thus determining its actual mass M_a.

By comparing the actual mass of the truck M_a with its calculated mass M_C the error of the weighbridge is determined.

If the difference between M_a and M_C does not exceed 0.1% of M_C the weighbridge is considered to be satisfactory.

Let us illustrate above method by a numerical example.

A 10-ton weighbridge is being checked.

Having checked, after technical inspection, the balance arm on a machine and the weighbridge with a load of 1 ton according to specification 15-52 it is necessary to ascertain that the moving pointer is deflected by 5 mm from the stationary one when 1 kg is added to a one ton load, i.e., that I. S. Krever's method can be used for checking the weighbridge.

After that:

1. The constancy of the weighbridge zero reading was checked by driving a ZIL-150 truck over it and no difference of readings was observed.

2. The same truck was weighed twice and the following readings were obtained:

a) with its rear wheels over the left-hand side knife-edge bearings - 773kg;

b) with its rear wheels over the right-hand side knife-edge bearings - 774kg;

3. At the same time the weight which deflected the moving pointer by 5 mm from the stationary one was determined. This weight was found to be equal to 2 kg (tolerance of 7.7 kg). Having thus established that the differences in the weighing did not exceed 0.01% of the maximum load and that the weighbridge sensitivity was satisfactory, the testing was proceeded with, and the carriage whose construction is shown in Fig. 2 was placed at the end of the balance arm.

4. The weighbridge was calibrated, and the "value of 1 ton" and the mass of the truck determined by means of second-grade weights:

a) with 1 ton placed in the middle of the weighing platform $P_1 = 96.4$ g;

b) the mass of the truck with its rear wheels over the left-hand side knife-edge bearings was $A_1 = 750.3$ g;

c) when a 1 ton weight was added over the right-hand side knife-edge bearings the reading was $B_1 = 846.7$ g;

d) the mass of the truck with its rear wheels over the right-hand side knife-edge bearings was $A_2 = 750.3$ g;

e) when a 1 ton weight was added over the left-hand side knife-edge bearings the reading was $B_2 = 846.7$ g.

Hence, the mass of the truck was

$$M_1 = \frac{A_1 + A_2}{2} = \frac{750.3 + 750.3}{2} = 750.3 \text{ g}$$

$$P_2 = B_1 - A_1 = 846.7 - 750.3 = 96.4 \text{ g};$$

$$P_3 = B_2 - A_2 = 846.7 - 750.3 = 96.4 \text{ g}.$$

The " value of 1 ton " was

$$P = \frac{P_1 + P_2 + P_3}{3} = \frac{96.4 + 96.4 + 96.4}{3} = 96.4 \text{ g}.$$

The calculated mass of the truck was

$$M_c = \frac{M_1}{P}.$$

Thus the calculated mass of the truck was equal to 7.783 tons.

5. The actual mass of the truck was determined by removing the standard weights from the carriage and the weighing platform and balancing the weighbridge by means of the sliding weights on the weighing arm.

It was found that

$$M_a = 7774 \text{ kg}.$$

6. The weighing error was determined

$$M_a - M_c = 7774 - 7783 = -9 \text{ kg}.$$

Since the specified tolerance of the weighbridge with a load of 7.783 kg must not exceed 7.8 kg the above weighbridge was rejected.

Despite its complications I. S. Krever's method is the most acceptable of all the existing methods.

Until the test and repair organizations are supplied with weight-testing trucks the use of this method should be permitted in addition to the ballast-load method, since the tests carried out by the Sverdlovsk branch of the VNIIM in 1958 and 1959 confirmed that the errors which can occur when this method is used do not exceed those of the ballast-load method.

From the practical point of view this method is better since it is considerably more productive. Moreover, in the overwhelming majority of cases it is difficult to find ballast loads for replacing standard weights on the sites where the weighbridges are tested, whereas it is always easy to find a loaded truck.

LITERATURE CITED

[1] Ya. I. Keimakh, Izmeritel'naya Tekhnika, No. 10, 1959.*

PORTABLE UNDISMOUNTABLE SCALES

I. N. Selezneva and M. V. Petkevich

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 11-12, March, 1960

The Novosibirsk State Institute of Measures and Measuring Instruments produced undismountable portable scales for state inspection work involving loads not exceeding 2 kg. The attached figure shows the scales in an operating condition.

One fulcrum and three load-carrying knife-edge bearings are rigidly fixed to balance arm 1. The scales have a tare regulator 2 and a center-of-gravity regulator 3.

The balance of the scales is judged by the position of the pointer, which is fixed to the straight end of the balance arm, with respect to scale 4, mounted on the balance-arm support.

The balance arm is fixed to the case by means of a stirrup suspension. The balance-arm suspension consists of a double hinge, thus allowing the arm to take up automatically a horizontal position.

Scale pans 5 consist of circles with opposite segments cut off. The pan suspended from the short balance arm is ribbed for holding securely the nominal 2 kg weight.

The bottom of the case has pan stops 6 mounted on it.

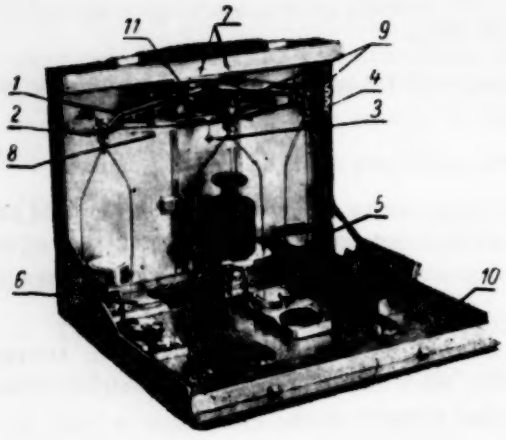
A sliding mechanismconsisting of retaining washer and two pins 7 is provided for moving the balance arm with its pans in and out of the case for transport and measurements.

When the case is being closed its lid presses against the pins and the washer, which in moving inside the case pushes with it the balance arm with its pans.

The back side of the case has a door which can be opened when checking nominal weights.

A set of special weights is fixed to the lid of the case. Weights from 20 g to 10 mg are kept in a box and the remaining weights (two of 200 g each, one of 100 g and one of 50 g) are fixed in pairs in special sockets.

*[See English translation].



When the testing is completed and the lid of the case is being closed, the balance arm is lifted on special guiding rails 8 while it is being displaced inside the case, and the fulcrum knife-edge bearing is lifted off its pillow block. Beveled sockets 9 in the stirrup suspensions engage with the beveled grooves in plugs 10, thus lifting the pillow blocks off the knife-edge bearings and securing the stirrups. The pans are held between rubber pads. The balance arm and suspension 11 are also stopped from moving by means of stops with rubber pads.

This arrangement provides good protection for the scales during transportation.

The arms ratios of the equal and the short arms are respectively 1: 1 and 1: 5; the largest loads are 200 g and 2 kg; the smallest are 1 g and 500 g; graduations with the largest loads are 20 mg and 100 mg; the error due to unequal arms in weighing with the largest loads is not greater than 50 and 400 mg; the period of the scales' oscillations is 11 to 17 sec.

The total weight of the scales in the case is 3.3 kg and its over-all dimensions are (in the case) 330 × 270 × × 55 mm.

These scales have undoubted advantages as compared with those previously produced. Thus only 1 min is required to prepare the scales for measurements; it is in fact only necessary to open the case and turn the handle of the end stop. The existence of pan stops is convenient for operation and protects the knife-edge bearings from shocks. The small weight of the scales is also an advantage.

Editorial Note. Above scales are undoubtedly convenient for outside inspection work owing to their portability, small weight, and the speed with which they can be made ready for measurements (1 min).

The scales, however, can only measure weights up to 2 kg, whereas there are weights of 5, 10 and 20 kg in common use.

The NGIMIP is at present developing portable scales for a maximum load of 5 kg.

The Editorial Board hopes to receive comments from the readers of this journal on which scales should be adopted for agencies of the Committee and their suggestions and wishes on the production of other reference scales.

DIFFERENTIAL RESISTANCE HIGH-PRESSURE GAUGES

M. K. Zhokhovskii and V. V. Bakhvalova
Translated from Izmeritel'naya Tekhnika, No. 3, pp. 12-15, March, 1960

Application of differential resistance high-pressure gauges for measuring deformation errors in piston pressure gauges was briefly mentioned in [1]. Below we give a description and an analysis of such a pressure gauge (Fig. 1) and cite other examples of its application for high-pressure experiments.

The body 1 of the instrument carries transducers 2 and 3 with resistance coils 4 and 5. The transducers are sealed by means of normal packing with an uncompensated area. Both ends of the coils are lead out by cone-shaped conductors. The cavities holding the coils are connected by channels 6 and 7 with the high-pressure sources P_1 and P_2 whose difference is to be measured. The supply channels, can be connected together or disconnected by means of needle 8 of the valve. The needle is actuated through piston 10 by pressure from a pump or hand press 9. For the compression of the needle's gland packing 11 a separate piston 12 is used, which is actuated by pressure from the pump feeding the lower portion of the pressure multiplier. When pressure is simultaneously exerted on the multiplier and on the compression of packing, a greater pressure is automatically established in the latter than that in the equipment. This condition is fulfilled with an appropriate choice of the dimensions of the packing and the piston. Above method of automatic compression is successfully used for sealing the rods of high pressure multipliers [2].

The pressure-gauge coils are connected to a normal bridge circuit with a compensating arm (Fig. 2), in which R_1 and R_2 are the initial resistances of coils 2 and 3, R_3 is a constant reference resistance and R is the resistance box initial resistance at which the bridge is balanced without any pressure in the gauge. The variation of resistance R_1 and R_2 are denoted by ΔR_1 and ΔR_2, and ΔR denotes the corresponding variation in the resistance box, which compensates the bridge unbalance caused by the effect of pressure changes.

If a differential pressure gauge is supplied, when the valve is closed, (Fig. 1), with two pressures p_1 and p_2 and if $p_1 = p_2$, we shall obtain from the condition of bridge balance that

$$\frac{R_1+\Delta R_1}{R+\Delta R}=\frac{R_2+\Delta R_2}{R_3},$$

whence,

$$\Delta R=R_3\frac{R_1+\Delta R_1}{R_2+\Delta R_2}-R.$$

For an equal arm bridge ($R_1 = R_2 = R_3 = R$)

$$\Delta R=\frac{R(\Delta R_1-\Delta R_2)}{R+\Delta R_2}$$

Since ΔR_2 is small compared with R we have

$$\Delta R=\Delta R_1-\Delta R_2. \qquad (1)$$

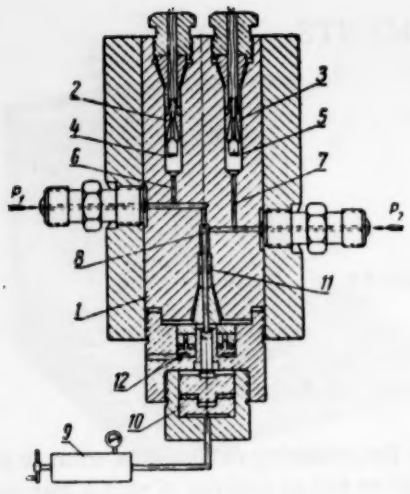


Fig. 1.

Fig. 2.

Let us express ΔR_1 and ΔR_2 by means of pressure $\Delta R_1 = k_1 R p_1$ and $\Delta R_2 = k_2 R p_2$, where k_1 and k_2 are the piezoelectric coefficients of the resistance coils. If the material of both coils is the same, $k_1 = k_2 = k$. Substituting the values of ΔR_1 and ΔR_2 into (1) we have:

$$\Delta R = kR(p_1 - p_2). \tag{2}$$

The value of $\Delta R/kR$ is equivalent to a certain pressure Δp and therefore (2) can be represented as

$$\Delta p = p_1 - p_2. \tag{3}$$

Thus the measured resistance ΔR immediately determines the difference of pressures exerted on the pressure gauge.

In constructing a pressure gauge it is difficult to obtain an absolute equality of the initial resistances of the coils and especially of the piezoelectric coefficients. These conditions need not be satisfied if the relation of the bridge readings to pressure are determined experimentally beforehand, by exerting pressure on both coils simultaneously (with an open valve). The bridge can also be calibrated for pressure differences with an open valve, thus eliminating the necessity of calculations and the determination of the piezoelectric coefficient of the coils.

The differential pressure gauge can be used for measuring directly each one of the pressures p_1 and p_2 exerted on it, and also for direct measurement of their difference. In the latter instance the gauge is especially suitable for measuring small differences of large pressures. For instance the gauge reads easily, with a normal bridge circuit and a standard galvanometer, differences of 0.2 kg per cm^2 at pressures of 7000 kg-wt/cm^2 [1]. The above figures do not necessarily indicate the limits attainable by the gauge, since the sensitivity of the bridge can in theory be raised if required and experience shows that resistance gauges can be used for measuring very high pressures.

If it is assumed that the differential pressure gauge will be first calibrated for pressure differences, then the systematic errors due to the difference in the initial resistance of the coils R_1 and R_2 and the variations of their piezoelectric coefficient with pressure will be practically eliminated. In this instance the accuracy of measuring the difference of pressures will in the long run depend on the consistency of the resistance-coil readings.

In order to determine the instability of the coil readings the following tests were carried out. Each coil of the gauge was supplied with its own source of pressure (multiplier) and a piston gauge with a top measurement limit of 10,000 kg-wt/cm^2. With the valve open the coils were loaded to the same pressure and the bridge reading was taken, then the valve was closed and one of the piston pressure gauges was loaded with a series of equal weights corresponding to given small pressure variations. The corresponding variations in the bridge readings were recorded. Such calibrations were made for various pressure differences and at different absolute pressures. For these measurements an ordinary bridge circuit was used with a resistance box, which was calibrated in 0.01 ohms, connected into one of the bridge arms; the resistance of each ratio arm amounted to some 100 ohms. A mirror galvanometer was connected to the bridge diagonal. The sensitivity of the circuit was such that a change in the resistance of 0.01 ohms produced a deflection of 160 divisions on the galvanometer, which is about 4.2 divisions for 1 kg-wt/cm^2.

Figure 3 shows the calibration curve for pressure differences of 2 to 200 kg-wt/cm^2 at pressures of 2,000 kg-wt/cm^2 and 5,000 kg-wt/cm^2, which confirms the linearity and almost complete independence of the calibration curve from absolute pressure. (Crosses represent pressure differences at 2,000 kg-wt/cm^2 and dots at 5,000 kg-wt/cm^2).

TABLE 1

Pressure difference kg-wt/cm²	Pressure, kg-wt/cm²	Resistance variations in terms of galvanometer graduations: reading	Resistance variations in terms of galvanometer graduations: mean value	Maximum deviation from the mean value, %
5	2000	21.5 20.5 21.5 22.0 22.0 22.0 23.0 21.5	21.7	6.0
10	1000	42.5 43.0 43.5 40.5 43.0 42.0 44.0 41.0	42.5	4.7
20	3000	84.0 85.5 85.5 86.5 85.5 84.0 86.5 83.3	85.1	2.1
40	2000	169.0 170.0 172.0 168.0 171.0 171.0	170.0	1.2

TABLE 2

Pressure difference, kg-wt/cm²	Variations (mean value) of the differential pressure gauge resistance, ohms: p=2000 kg-wt/cm²	p=5000 kg-wt/cm²	p=7000 kg-wt/cm²	p=9000 kg-wt/cm²	mean value	maximum deviation from the mean value, %
100	0.02535	0.02564	0.02549	0.02523	0.02545	0.9
200	0.05070	0.05122	0.05052	0.05032	0.05064	1.1

Table 1 shows separate series of observations for various pressure differences at several pressures. It will be seen from Table 1 that the deviation of individual measurements from the mean value even of such small differences as 5 and 10 kg-wt/cm² at pressures of 1,000 and 2,000 kg-wt/cm² did not exceed 6%; for larger pressure differences the error dropped to 1-2%.

Table 2 gives the mean values of resistances for various series of measurements obtained for pressure differences of 100 and 200 kg-wt/cm² at pressures of 2,000 and 9,000 kg-wt/cm². These data also confirm the absence of any systematic relation between variations of resistance and absolute pressure.

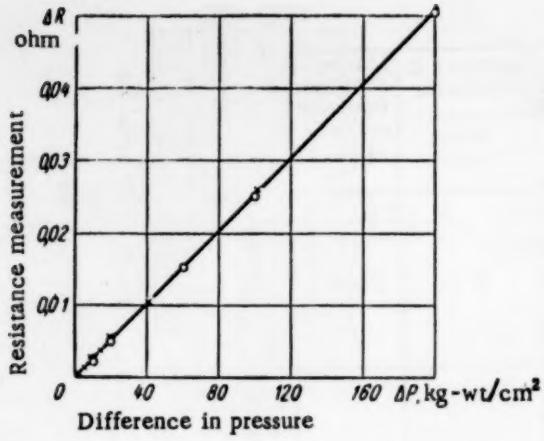


Fig. 3.

CONCLUSIONS

Above tests of the differential pressure gauge are not exhaustive, yet they confirm the exceptionally wide possibilities of its utilization for measuring small pressure differences at very high absolute pressures. In addition to the case under consideration [1] the differential pressure gauge can be used for investigating the fusing of substances under pressure by the method of "clogging" a capillary tube, for determining the pressure difference due to overcoming friction or to compressing a bellows in piston or bellows wave-pressure gauges, for detecting similar pressure differences in various types of separators and other similar cases.

Precision measurements of pressures by means of the differential pressure gauge are of special interest in such cases when a direct connection of a piston pressure gauge is for some reason impossible. In such cases one of the differential pressure-gauge coils is connected to the equipment under test and the other to the piston pressure gauge, which is supplied with its own source of pressure. By means of the latter source the pressure in the piston gauge is raised until it becomes equal to that in the equipment under test. At the instant when the difference of the two pressures becomes equal to zero, according to the reading of the differential pressure gauge, the actual pressure in the equipment under test is determined directly by the reading of the piston gauge.

In the above instances of the application of the differential pressure gauge, the theoretical side of the problem has been dealt with. In the practical application of the instrument, some modifications or additions to the design may be required according to the object of the tests, these alterations will not affect, however, the principle of its operation.

LITERATURE CITED

[1] M. K. Zhokhovskii, Izmeritel'naya Tekhnika, No. 7, 1959.*

[2] V. A. Borzumov and D. S. Mirinskii, Pribory i Tekhnika Eksperimenta, No. 3, 1959.*

CALIBRATION OF THREE-COMPONENT DYNAMOMETERS

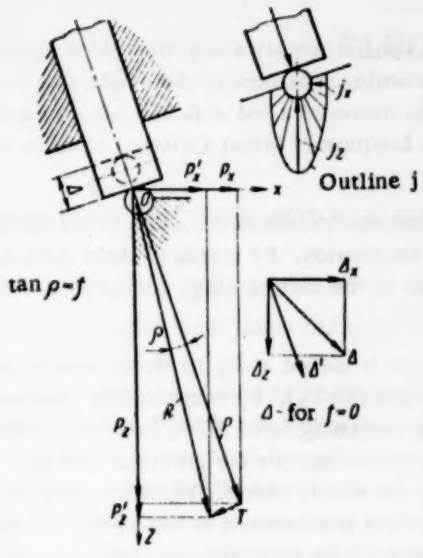
V. F. Paramonov

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 15-16, March, 1960

Loading of systems along three coordinates by means of one space-directed force is often used in practice for investigation and measurement, for instance, in calibrating three-component lathe dynamometers, in investigating and testing the stiffness of machine tools, and in other cases.

It is known that with a separate calibration of each dynamometer component it is impossible to determine the error due to the interaction effect of the components of a force on the dynamometer readings, and major attention is, therefore, paid to the use of equipment and devices which provide a loading of the system simultaneously along the three components. Calibration devices used for this purpose are often very inaccurate in determining the value of the components which act on a loaded dynamometer or some other elastic system [1, 2, 3].

*[See English translation].



The use of such devices will always lead to a discrepancy between calibrations obtained by simultaneous loading of all the three components and those obtained by loading them separately. Therefore [1, and 2] in fact do not provide an analysis of the errors in dynamometers of various makes due to the effect of the interaction of the components on the dynamometer readings, but illustrate in the main the inaccuracies of the calibration method employed by the authors.

The principle of operation of these devices consists in replacing the dynamometer cutter by a holder with a ball, whose center coincides with the point at which the forces is applied (see figure). The rod by means of which pressure is exerted operates in a rigid bushing, whose axis is placed at the required angle to the dynamometer. A reversed arrangement is also used, in which the rod is terminated in a ball and the holder has a flat working surface which is directed perpendicular to the action of the force, but in both cases a similar phenomenon occurs which consists of the following. Being an elastic system, the dynamometer has different stiffnesses in the direction of its three axes P_z, P_y and P_x.

During calibration the direction of the applied forces does not usually coincide with any of the stiffness ellipse axes. This circumstance not only produces a displacement of the point of contact in the direction of the rod movement, but also makes the ball slide along its contact surface. Due to the latter effect an additional friction force T is produced which has not been previously taken into account.

For the sake of simplicity let us examine this effect in a single plane ZOX. Let the graduated dynamometer be designed for a ratio of maximum component values of $P_x/P_z = 1/3$, and let its stiffness in the direction of the j_x and j_z components of the cutting effort be approximately proportional to the maximum values of the latter components; this condition is normally observed in designing for approximately equal measurement displacements.

Let us assume that during calibration the rod axis is placed in plane XOZ and forms with the OZ axis an angle whose tangent is 1/3. If we also assume that at the point of contact O there is no friction whatsoever, and that force P is exerted on the rod, we shall obtain for the ball a displacement Δ which can be resolved along the axes:

$$\Delta_z = \frac{P_z}{j_z} \text{ and } \Delta_x = \frac{P_x}{j_x}.$$

Since

$$\frac{j_x}{j_z} = \frac{P_x}{P_z}, \text{ and } \frac{P_x}{j_x} = \frac{P_z}{j_z},$$

hence $\Delta_x = \Delta_z$.

In this case the direction of the displacement of the rod and the holder do not coincide (at the point of contact) thus producing slipping, which provides an additional friction force T, whose sum with force P constitutes the acting force R registered by the dynamometer.

It can be easily seen from the figure and demonstrated by calculation that with an angle between the direction of P and R equal to the angle of friction ρ (of steel against steel) the actual value of P'_z exerted on the dynamometer will be considerably larger than the apparent value P_z, and the actual P'_x will on the contrary be smaller (by about 31%) than the apparent P_x determined without taking friction into account.

In practice, due to a certain amount of give in the calibrating device the error is smaller, but nevertheless for P_x it may attain 25%.

Hence, in designing devices intended for loading elastic systems simultaneously along their three components, it is necessary either to exert the force by means of flexible tensile transmission as used in the calibrating instruments designed by the author and described in [4], or exert the effort by means of a rod with ball supports and a built-in dynamometer as used by the Experimental Scientific Research Institute of Metal-Cutting Lathes in their devices for checking the stiffness of lathes.

The author used two methods of calibration for checking and adjusting dynamometers, both based on different types of loading in which the effort was exerted by tension instead of compression. By means of these devices dynamometers were adjusted during their manufacture so that the interaction of the cutting-effort components was almost completely eliminated.

In the first method the dynamometer which is mounted on the lathe is loaded along its three coordinates by means of two other dynamometer (for P_y and P_x) and a lever with a weight (for P_z). P_x is applied by tensioning the tail-stock spindle, and P_y by means of an cantilever bracket with a tensioning screw fixed in a tool holder. In order to increase the accuracy of measurement the indicating spring dynamometers are provided with four measuring ranges by varying the point of application of the force along the elastic plates. The lever used for applying P_z is suspended on two stirrups one of which serves as a support and is connected to the stand, and the other transmits the effort to the holder. The perpendicularity and crossing of the three applied efforts is checked by means of a goniometer and a level with respect to the direction of the draw wires or cables.

The second method consists in loading the dynamometer along the three components by means of one effort R. The dynamometer is fixed in space by means of two swiveling machine cramps in such a manner that its resultant force R is vertical.

The first cramp is fixed to a vertical plane (the table of a transverse planing machine) and provides rotation in the YOZ plane through the required angle ψ. The second cramp is fixed at right angles in the jaws of the first and provides rotation in the XOZ plane through angle ω.

The tool-holder which carries the dynamometer is fixed in the jaws of the second cramp. The loading is accomplished by suspending weights which transmit the effort by means of a bracket to the supporting point of the holder. Instead of the cramps two turntables connected by means of an angle bracket can be used. For large forces either a lever with two stirrups is used, similar to the arrangement used for load P_z in the first method, or a screw and a dynamometer, similar to the arrangement for P_y in the same method.

After loading the angles of rotation of the dynamometer are checked by means of goniometers and a level. The values of the effort projections along the main, radial and axial components are determined from the following formulas:

$$P_z = R\frac{\cos\omega}{\sqrt{1+\operatorname{tg}^2\omega\cos^2\psi}};$$

$$P_y = R\frac{\sin\psi}{\sqrt{1+\operatorname{tg}^2\omega\cos^2\psi}};$$

$$P_x = R\frac{\sin\omega}{\sqrt{1+\operatorname{tg}^2\psi\cos^2\omega}}.$$

LITERATURE CITED

[1] P. G. Terlikov, Vestnik Mashinostroeniya, No. 11, 1954.

[2] A. A. Voronin, Vestnik Mashinostroeniya, No. 10, 1955.

[3] L. P. Medvedev, High-Speed Cutting at a Rapid Feeding Rate [in Russian] (Mashgiz, 1955).

[4] V. A. Bobrovskii, Vestnik Mashinostroeniya, No. 1, 1955.

ELECTRICAL MEASUREMENTS

A SEMICONDUCTOR SOURCE OF STANDARD (REFERENCE) VOLTAGES

Yu. R. Nosov

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 17-18, March, 1960

Electronic measuring and controlling circuits often include a standard voltage source. Galvanic elements or gas-discharge devices are normally used for this purpose. In recent years low-tension silicon diode-stabilizers are becoming widely used for reference voltages [1, 2, 3, 4]. Their decisive advantages include economy, small dimensions, a practically endless life, a low resistance of the diode in the stabilization range. The existence, in the reverse voltampere characteristic of the stabilizer, of a range with a low inverse resistance R_Z (Fig. 1) is due to the avalanche breakdown in silicon p-n junctions [5, 6].

In the simplest circuit for a silicon diode reference-voltage source (Fig. 2) the instability of the output voltage U_O is expressed by

$$\Delta U_o = \Delta U_i \frac{R_z}{R_1}.$$

The effect of input voltage variations on the stability of the output voltage is even smaller in the circuit of Fig. 3. Here

$$\Delta U_o < \Delta U_i \frac{R_{z_1}}{R_1} \cdot \frac{R_{z_2}}{R_2}.$$

If for instance $R_1 = R_2 = 1$ kilohm, and stabilizers D811 ($R_Z \leq 15$ ohms) and D808 ($R_Z \leq 6$ ohms) are used in the first and second positions, then $\Delta U_O < 10^{-4} \Delta U_i$. By such means the output voltage can be made practically completely independent of input-voltage variations. In such a case the instability of the output voltage is determined entirely by the variations due to temperature of the breakdown voltage U_Z of the stabilizer. This variation is very small (less than 0.1%/°C in Soviet-made 7-14 volt stabilizers type D808-D813), however, for a number of precision measurements even this drift is not permissible.

The examination of the temperature shift in the forward and reverse portions of the voltampere characteristic of a silicon diode indicate the possibility of greatly increasing the thermal stability of a reference voltage source.

The theoretical and experimental formula for the breakdown voltage U_Z of a silicon diode is [3]

$$U_{zT} = U_{zT_0}[1+\alpha(T-T_0)], \tag{3}$$

where α is a constant determined by the resistivity of silicon; T is the absolute temperature.

The temperature shift of the forward characteristic of a p-n junction is equal from [7] to

$$\frac{\partial U_f}{\partial T} = \frac{U_f}{T} - \frac{nkT}{q} \cdot \frac{\frac{c}{n} + T(1+\gamma)}{T^2},$$

where U_f is the forward voltage at a p-n junction; k is the Boltzmann constant; q is the electron charge; c is 12 900°K for silicon; n is the 1-2 for silicon [8]; γ is the index in the relation between the majority current carriers μ and temperature, given in the form $\mu \simeq T^{-\gamma}$.

Tests have shown that for Soviet-made silicon diodes n = 1.5. Diodes made of n-silicon have a $\gamma = 2.6$ [9]. In stabilizers made of a very low resistivity silicon (ρ = 0.03-0.08 ohm .cm) the value of γ is lowered approximately by 10% owing to the electron dissipation in ionized atoms of donor substances [10].

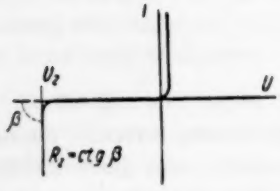


Fig. 1.

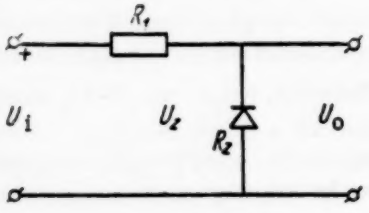


Fig. 2.

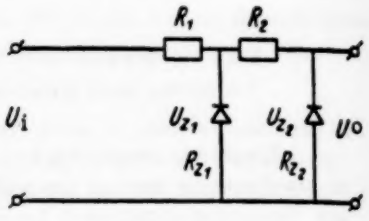
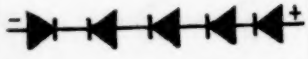


Fig. 3.

TABLE 1

Circuit	U_z, V	Differential resistance R_{dif}, ohm	Variations of U_z in the range of 0-120 °C, v
D813	12.1₇	≃15	0.93
D809 	12.1₃	≃35	0.01

Calculations on the basis of (3) and (4) and tests give for diodes type D808-D813

$$\frac{\partial U_z}{\partial T} = (3-10)\ \text{mv °C}$$

$$\frac{\partial U_f}{\partial T} = -(1-1.5)\ \text{mv °C}$$

The similarity of the absolute values of $\partial U_z/\partial T$ and $\partial U_f/\partial T$, and their opposite signs make it possible to compensate them mutually. A circuit consisting of five series-connected silicon stabilizers was assembled for this purpose in such a manner that one of them worked, when the current was switched on, in the breakthrough region and the remaining four operated in the forward transmission region.

Comparative parameters of this circuit and a single diode are given at a current of 5 ma in Table 1.

It will be seen from Table 1 that it was possible by means of thermal compensation to reduce the variations of voltage U_z by almost two decimal places. In the case of the series connection, a certain rise in R_{dif} is, naturally, observed, but it remains sufficiently small.

In the practical application of these circuits, attention should be paid to placing all the diodes under the same temperature conditions. It should also be remembered in designing these circuits that practically all the

TABLE 2

Group	R_z (ohms) for I_{rev} = = 1 ma	R_z (ohms) for I_{rev} = = 5 ma	U_z (v) for I_{rev} = 5 ma	U_f (v) for I_f = 5 ma.
D808	<12	< 6	7–8,5	≈0.7
D809	<18	<10	8–9,5	≈0.7
D810	<25	<12	9–10,5	≈0.7
D811	<30	<15	10–12	≈0,7
D813	<35	<18	11,5–14	≈0.7

power is dissipated in the diode connected in the reversed direction. This circumstance leads to a certain rise in the temperature of its p-n junction as compared with the remaining diodes, a rise which can be expressed by the formula [3]

$$T_{junction} = T_{ambient\ air} + aW, \qquad (5)$$

where W is the power dissipated in the stabilizer.

For stabilizers type D808-D813 a = 0.04 to 0.08°C/mw.

By a more careful selection of the compensating diode it is possible to reduce the voltage drift still further. A thermocompensated reference voltage source made by this method is simple, reliable and has relatively small dimensions.

The Soviet-made stabilizers' main parameters, required for designing thermocompensated circuits, are given in Table 2 (for temperatures + 20±3°C).

LITERATURE CITED

[1] D. H. Smith, Trans. AIEE, Communications and Electronics, No. 16 (1955).

[2] Chase, Hamilton, Smith, Bell Syst. Tech. Journal, 33 (1954).

[3] Toute la Radio, No. 224 (1958).

[4] Électronique Industrielle, No. 8 (1958).

[5] K. G. McKay and K. G. Afee, Phys. Rev., 91 (1953).

[6] K. G. McKay, Phys. Rev., 94 (1954).

[7] Yu. R. Nosov and B. I. Khazanov, Radiotekhnika, No. 13, (1958).

[8] M. Lin and E. Crosby, IRE Nat. Conv. Rec., 1957, No. 3.

[9] F. J. Morin and J. P. Maita, Phys, Rev., 96 (1954).

[10] E. M. Conwell, Proc. IRE, 40 (1952).

HIGHLY STABLE DC VOLTAGE SOURCES FOR MEASURING CIRCUITS

R. F. Kozlov

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 18-19, March, 1960

In various measurements low-voltage sources with relatively high currents are often required. Below we suggest a stabilizing circuit which can replace 2.5 to 24 v storage batteries and which possesses a highly stable output voltage.

Figure 1 shows a stabilizer circuit for 2.5 v and a maximum load current of 0.6 amp. The rectifier consists of germanium diodes DGTs-21. A 1 amp fuse F_2 protects the controlling transistor FT_1 from burning out if the output of the circuit were shorted. Transistor FT_1 is of the P4D type, the remaining transistors of the P6A type. The reference voltages E_1 and E_2 are provided by dry cells FBS-0.25. Cell E_1 is charged by the base current of transistor FT_7 and cell E_2 discharges with a current of 1 μa. Relay S disconnects the dry cell circuits when the stabilizer is switched off the mains. Potentiometer R_{11} provides a variation of several percent in the output voltage U_O without affecting the stabilization factor. The output voltage can be set to 6-12 v. Its stabilization factor is 4,000. Its internal resistance 0.1 ohm. Its drift during the first 10 min after switching on is 0.4% and later does not exceed 0.01% in one hour.

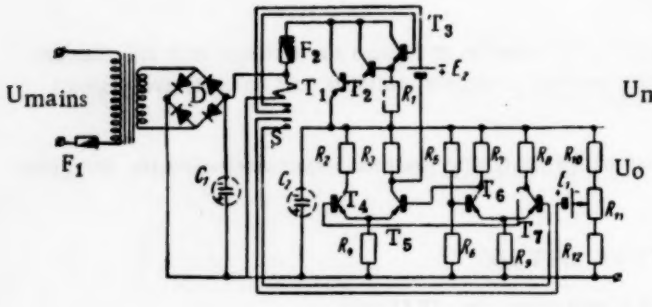


Fig. 1.

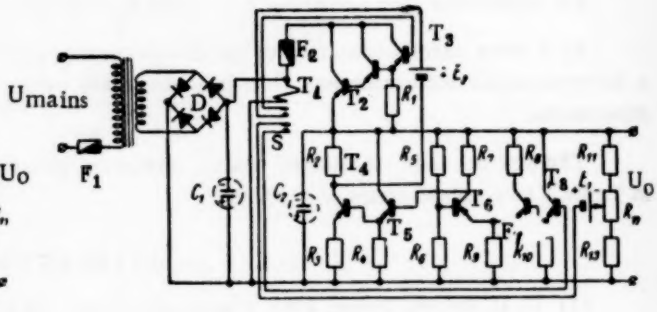


Fig. 2.

The circuit data are: C_1 = 1,000 μf; R_1 = 2 kilohms; R_2 = 2.6 kilohms; R_3 = 3.7 kilohms; R_4 = 1 kilohm; R_5 = 2.4 kilohms; R_6 = 47 ohms; R_7 = R_8 = 3.6 kilohms; R_9 = 140 ohms; R_{10} = 8 ohms; R_{11} = 25 ohms and R_{12} = 18 ohms.

Figure 2 shows a 24 v stabilizer circuit for a maximum current of 300 ma. Dry cells type 13 AMTsG-0.5 serve as reference voltages. The currents flowing through the cells amount approximately to 1-1.5 μa. Transistor FT_1 of the P4D type the remaining transistors being of the P13A type. The circuit stabilization factor is 40,000; its internal resistance 0.05 ohms. The output-voltage drift during the first hour after switching on is 0.4% and thereafter 0.001% per hour. Its output voltage can be set at 28 to 40 v.

The circuit data are: C_1 = C_2 = 500 μf; R_1 = 1.5 kilohms; R_2 = 12.5 kilohms; R_3 = 800 ohms; R_4 = 2 kilohms; R_5 = 2.4 kilohms; R_6 = 60 ohms; R_7 = R_8 = 23 kilohms; R_9 = 250 ohms; R_{10} = 1.3 kilohms; R_{11} = 400 ohms; R_{12} = 50 ohms and R_{13} = 500 ohms.

The ripple at the output of the circuit is less than 1 mv.

SINGLE SLIDE-WIRE RECTANGULAR-COORDINATE AC COMPENSATORS

L. F. Kulikovskii and A. L. Tsiber

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 19-22, March, 1960

In the existing compensators of the rectangular-coordinate (complex) type [1, 2, 3] using phase-sensitive unbalance indicators the balancing process is attained by means of sequential approximations, thus taking a relatively long time.

In complex type compensators with phase sensitive unbalance indicators [4, 5] the orthogonal components of the vector under test are balanced alternately thus reducing the balancing time to 1/5 or 1/6 of the original. The phase-sensitive unbalance indicator also provides an immediate indication of the quadrant of which the voltage vector is measured by the deflection of the indicator pointer to the right or the left of the zero position.

In order to provide a greater unbalance sensitivity, phase-shifting networks are usually added to the indicator excitation and the compensation-resistance circuits. During measurements by means of such compensators the registering and phase-shifting devices are used alternately.

By using phase-sensitive unbalance indicators in the complex compensator circuit, it becomes possible to utilize the same registering and phase-shifting devices first for measuring one of the components of the voltage (or emf) under test, and then for measuring the other orthogonal component of the voltage. This principle was used in the design of the instrument for checking electrical equipment [6]. This principle is also used in designing the single slide-wire, ac complex compensator [7] (Fig. 1).

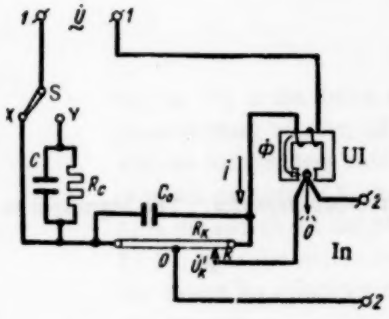


Fig. 1. UI is the phase-sensitive unbalance indicator (an electrodynamic or ferrodynamic galvanometer with independent excitation); R_k is a registering device (slide wire); S is a switch of the phase-shifting device R_cC.

The supply voltage $\dot{U}$ is connected to terminals 1-1 of the device, and the voltage (emf) $\dot{E}_i$ under test to terminals 2-2. Current $\dot{I}_i$, which is produced by voltage E_i, flows through the galvanometer coil (Fig. 2), and interacts with the magnetic flux Φ_m, produced in the galvanometer gap by the excitation current $\dot{I}$. If the field in the galvanometer gap and the current in its coil are sinusoidal and of the same frequency, the mean value of the torque which acts in the moving system of the galvanometer will be determined by the equation:

$$M = c\,\psi\,I_i\cos(\hat{\dot{\psi}};\hat{\dot{I}_i}), \tag{1}$$

i.e., the rotation of the moving system is only produced by the coil current component which is in phase with the magnetic flux, that is by the real component

$$I_i\cos(\hat{\dot{\psi}};\hat{\dot{I}_i}) = I_{ix}. \tag{2}$$

In order to compensate the effect of this component and thus measure it, a compensating voltage $\dot{U}'_{kx}$ is selected to produce in the measuring circuit a current $\dot{I}_{kx}$, which is in the opposite direction to current $\dot{I}_{ix}$ and equal to it in value (Fig. 3).

In other orthogonal component of the current $\dot{I}_i$-$\dot{I}_{iy}$ can be measured in a similar manner. For this purpose the operating current is rotated by means of a phase-shifting device through 90°, thus making the phase sensitive unbalance indicator register the second orthogonal component of the voltage under test.

At the instant of balancing (compensation) of one of the components of the voltage under test (for instance the one coinciding with direction I_{ix}) the other component remains uncompensated and will, if suitable measures are not taken, and the circuit impedance Z_k is finite, produce in the object under test power dissipation equal to

$$P = \frac{U^2_{\text{uncom}}}{z_k} = \frac{E^2_{iy}}{z_k}. \tag{3}$$

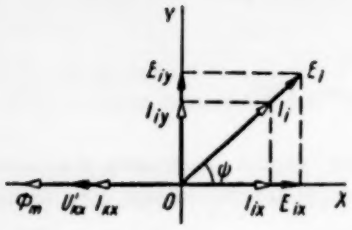


Fig. 2.

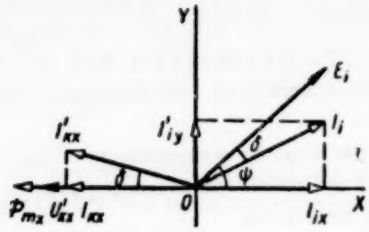


Fig. 3.

The current then flowing through the circuit

$$I_{\kappa y}=\frac{E_{iy}}{z_{\kappa}} \tag{4}$$

will produce an error in determining the components of the voltage under test. The effect of the uncompensated current will be especially noticeable if the object under test contains nonlinear circuits. Moreover with incomplete compensation any reactance of the measuring circuit directly affects the error in determining the components of the measured voltage. Figure 3 shows the vector diagram of the currents and voltages acting in the measuring circuit when its impedance is inductive. The measuring-circuit current will, depending on the magnitude of the reactance in the circuit, be retarded in phase with respect to the measured voltage by angle δ.

The registered value of the compensating voltage in the presence of angle δ is always larger than the voltage required for balancing when $\delta = 0$.

The modulus of the measured voltage is represented by

$$E_i=\cos\delta\sqrt{(U'_{\kappa x})^2+(U'_{\kappa y})^2}, \tag{5}$$

where U'_{kx} and U'_{ky} are components of the measured voltage registered on the compensator. The argument is found from the expression

$$\psi=\tan^{-1}\frac{U'_{\kappa y}}{U'_{\kappa x}}+\delta. \tag{6}$$

It follows from (5) and (6) that in order to determine the modulus and argument of the vector it is necessary either to know angle δ, or to eliminate it by means of compensation. Angle δ can be determined by introducing into the circuit an additional known voltage [6]. The reactance of the circuit is compensated by introducing into it an RC network.

In order to reduce to the minimum the power taken from the object under test, it is advisable to have at the single slide-wire compensator input an electronic device with a high impedance input. * The schematic of such a compensator is shown in Fig. 4. The electronic device used consists of an unbalance-voltage amplifier.

*Any double slide-wire compensator can be represented, owing to the insensitivity of the unbalance indicator, by an equivalent input impedance

$$z_{eq}=\frac{U_{in}S}{\sqrt{2\beta}}z_{\kappa}$$

where U_{in} is the voltage fed to the input of the compensator, v; S is the sensitivity of the unbalance indicator, mm/mv; z_k is the impedance of the measuring circuit, ohms; β is the indicator deflection which is noticeable by the naked eye, in divisions of the scale, mm. For U_{in} = 1 v, S = 5 mm/mv, z_k = 50 ohms; β = 0.25 mm, z_{eq} = 700 kilohms.

Variations in the gain of the electronic device only affect the sensitivity of the compensator, but a phase difference between the input and output voltages of the amplifier can introduce an error in determining the components of the measured voltage. It is, therefore, necessary to check before beginning measurements the phase difference between the amplifier input and output voltages.

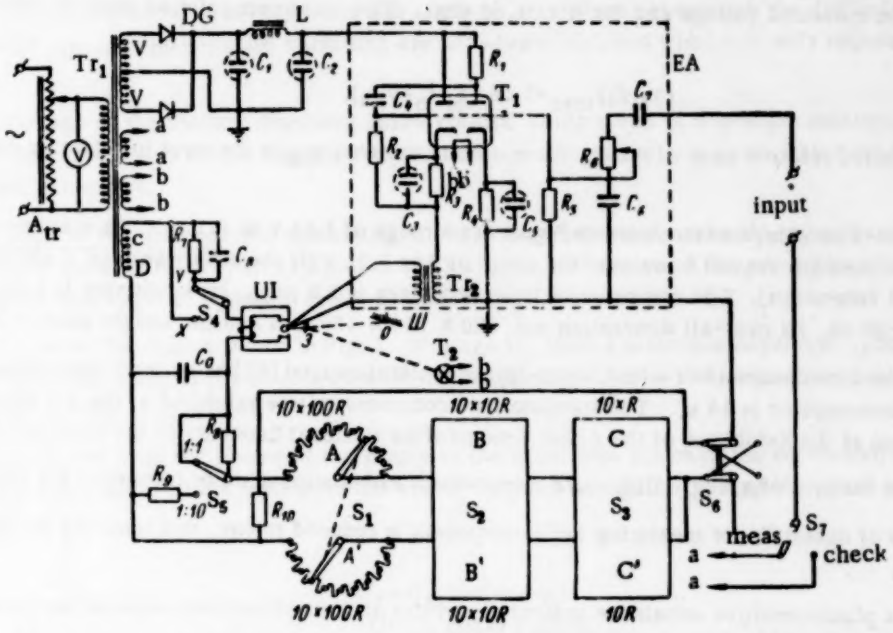


Fig. 4. Tr_1 is the mains transformer; Tr_2 is the isolating transformer; R_7C_8 is the phase shifting circuit; UI is the unbalance indicator (a ferrodynamic galvanometer with an independent excitation); T_1 is the electron tube (a double triode with separate cathodes); S_1, S_2 and S_3 are the switches for the compensation resistors; S_4 is the switch of the phase shifting device; S_5 is the switch for dividing the scale by 10; S_6 is the switch for setting the direction of the compensating voltage; S_7 is the switch for checking the phase difference between the amplifier input and output voltages.

Measurements by means of the compensator are carried out in the following manner. The measured voltage (emf) E_i is fed to the "Input" terminals; this makes the moving system of the unbalance indicator UI deflect away from the neutral position. By connecting to the input of the electronic amplifier EA a compensating voltage, obtained from a registering device, and equal to one of the components of the voltage under test the pointer of the unbalance indicator is returned to zero. The value of the component is determined from the reading of switches S_1, S_2 and S_3. After switching over S_4 the other component of the tested voltage is measured. The phase difference between the amplifier input and output voltages is checked (with a shorted input) by throwing switch S_7 into the "Check" position, switch S_4 into the "X" position and setting switches S_1, S_2 and S_3 into positions corresponding to the compensating voltage equal to the voltage component $(U_{aa})_\gamma$. The zero phase difference is set by means of resistance R_6.

The compensator sensitivity is determined by the gain of the electronic amplifier and the sensitivity of the unbalance indicator

$$S_k^U = K_{ea} \cdot S_{UI}^U \qquad (7)$$

The sensitivity of the unbalance indicator (a ferrodynamic galvanometer with an independent excitation) can be determined from the expression

$$S_{UI}^{U} = \frac{0.1\, B_{eff}\, S_p \cos(\psi - \delta)}{W z_k + \omega B^2_{eff}\, S_p^2 \sin\delta \cdot 10^{-9}}, \quad (8)$$

where B_{eff} is the magnetic induction in the gap, gauss; S_p is the area of the coil, cm^2; W is the specific opposing moment due to the twisting of the strip suspensions, dyne·cm/rad; z_k is the measuring-circuit impedance, ohms; δ is the angle of lag of the measuring circuit current with respect to the voltage which produced it, in degrees; ψ is the angle between the measured voltage and the X axis, in deg. The maximum referred error in determining the modulus is:

$$(\gamma_{rf} E_i)_{max} = 1.55\,(\gamma_{rf} I_o + \gamma_{Rk}), \quad (9)$$

where $\gamma_{rf} I_o$ is the referred relative error of setting the operating current; γ_{Rk} is the error in selecting compensation resistors.

The single slide-wire compensator shown in Fig. 4 has a range of 1.11 v to 111 mv. Its maximum absolute error of measurement does not exceed 5 mv over the range of 0 to 1.11 v (if the supply voltage is checked by means of a grade 0.2 voltmeters). The compensator input resistance is 1.5 meg. Its sensitivity is 5 div/mv. The power consumption –20 va. Its over-all dimensions are 320 × 250 × 130 mm and the weight about 6 kg.

The single slide-wire compensator whose input device is transistorized [8] has an input impedance of 0.5 meg, and its power consumption is 14 w. The transistorized compensator was exhibited at the All-Union Industrial Exhibition in 1958 and at the Exhibition of the Achievements of the National Economy of the USSR in 1959.

The distinctive features of a single slide-wire compensator either with tubes or transistors are the following:

1) the number of operation for measuring each component is reduced to one, thus reducing the measuring time to a minimum;

2) the use of a phase-sensitive unbalance indicator provides an immediate indication of the quadrant in which the voltage is measured;

3) the accuracy of measurement does not depend on the nature of the internal impedance of the object under test;

4) the magnitude of the internal impedance of the measured object hardly affects the sensitivity of the compensator (measurements were made with an object which had an internal impedance up to 10 kilohms).

5) if the value of one of the components is small it can be measured on a scale whose calibrations are divided by a factor of 10, thus raising the accuracy of measurement.

The single slide-wire tube and transistorized compensators were made by the Department of Automation, Telemetering and Measuring Instruments and Devices of the Kuibyshev Industrial Institute.

LITERATURE CITED

[1] V. I. Krotova, Potentiometers [in Russian] (VNIIM, Leningrad, 1940).

[2] G. L. Gornshtein, "Compensation ac equipment of the "Tochélektropribor" plant," Paper read at the Conference on Compensation Methods of Measurement [in Russian] (L'vov, 1955).

[3] I. M. Vanderleck, An AC Potentiometer, Electrical Engineering, 1948, No. 2.

[4] L. F. Kulikovskii, Élektrichestvo, No. 6, 1948.

[5] É. G. Atamalyan, "A phase-sensitive electronic null-indicator in an ac compensation circuit" Trans. Moscow Mechanical Institute [in Russian] (v. 3, 1952).

[6] L. F. Kulikovskii, "A universal instrument for checking electrical equipment" Trans. I. G. Es'man Energetics Institute [in Russian] (v. 8, Acad. Sci. Azer. SSR, Baku, 1947).

[7] A. I. Tsiber, Collection of Works of the Kuibyshev Industrial Institute [in Russian] (v. 7, Kuibyshev, 1958).

[8] Certificate of Registration No. 11091 of October 1, 1958.

A METHOD OF MEASURING THE LOSS ANGLE OF CAPACITORS

M. S. Mikitinskii

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 22-24, March, 1960

The lack of reference loss-angle standards for a sufficiently wide frequency range makes it impossible to use fully the substitution method in measuring loss angle on ac bridges. Moreover, the difficulties connected with the use of bridge circuits which require balancing are not always justified when it is only required to measure the loss angle.

The advantage of the method described below consists in the speed of loss-angle measurements. It will also be shown how it is possible to eliminate (partially) in this case the systematic errors which are normally avoided in the substitution method.

The essence of the method. For measuring "linear" capacitors it is advisable to use Sawyer and Tower's method [1] which was modified by A. L. Khodokov [2] who drew attention to the possibility of applying the circuit for measuring the loss angle of a normal (linear) capacitor.

Let us examine the circuit shown in Fig. 1. Voltage U_y from a reference capacitor C_0 and reference resistor R_0 is fed to the vertical plates of a cathode-ray oscilloscope. C_1 and R_1 are, respectively, the capacitance and losses of the measured capacitor.*

Voltage U is fed from the source of the supply to the horizontal plates of the oscilloscope. The phase relations which will then exist are seen from the vector diagram in Fig. 2. Taking the phase of current i as the basis we have

$$\begin{aligned} U_y &= U_{y0}\sin(\omega t+\varphi_0),\\ U &= U_0\sin(\omega t+\varphi_0+\beta). \end{aligned} \tag{1}$$

Eliminating variable t we obtain the equation of the curve seen on the oscilloscope screen:

$$U^2-2\frac{U_0}{U_{y0}}UU_y\cos\beta+\frac{U_0^2}{U_{y0}^2}U_y^2-U_0^2\sin^2\beta=0. \tag{2}$$

For $\varphi_1 \neq \varphi_2$ ($\beta \neq 0$) equation (2) describes an ellipse; for $\varphi_1 = \varphi_0$ ($\beta = 0$) this equation represents a straight line

$$U_y=\frac{U_{y0}}{U_0}U. \tag{3}$$

Equality $\varphi_1 = \varphi_0$ (phase balance) is equivalent to equality $\delta_1 = \delta_0$, where δ_1 is the loss angle of the capacitor under test and δ_0 the loss angle of the R_0C_0 network (a nonreactive resistance and "lossless" capacitor).

Circuit sensitivity. As the result of tests conducted up to a frequency of 20 kc it has been established that the sensitivity of the circuit shown in Fig. 1 depends to a great extent on the relations between its components.

Since it is undesirable to use amplifiers, owing to their phase distortions, the maximum sensitivity of the circuit acquires predominant importance.

In order to calculate the sensitivity of the circuit let us determine from (2) the value of the small semiaxis of the ellipse. According to the general methods of analytical geometry, the square of the small semiaxis is equal to

*The reasoning used for a series circuit can be easily applied to a parallel connection of R and C.

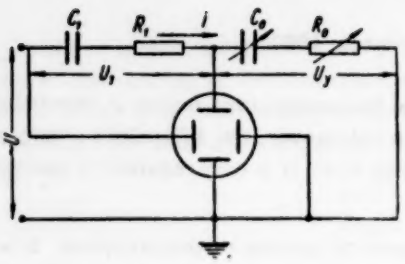


Fig. 1.

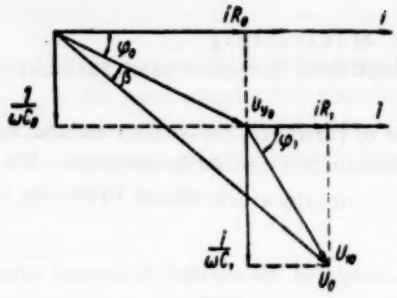


Fig. 2.

$$A^2=\frac{2U_0^2\sin^2\beta}{1+\frac{U_0^2}{U_{y0}^2}+\sqrt{1+2\frac{U_0^2}{U_{y0}^2}\cos 2\beta+\frac{U_0^4}{U_{y0}^4}}} \tag{4}$$

and after transformations

$$A^2=\frac{1}{2}\left(U_{y0}^2+U_0^2-\sqrt{U_{y0}^4+2U_{y0}^2U_0^2\cos 2\beta+U_0^4}\right). \tag{5}$$

Since (5) is too complicated and inconvenient to handle, let us simplify it for the case approaching phase equality. In this most relevant case

$$A^2=\frac{1}{2}\alpha, \tag{6}$$

where α, a quantity which can be made arbitrarily small, is found from the condition

$$\sqrt{U_{y0}^4+2U_{y0}^2U_0^2\cos 2\beta+U_0^4}=U_{y0}^2+U_0^2-\alpha. \tag{7}$$

We obtain from (7), by neglecting second order quantities

$$\alpha=\frac{U_{y0}^2U_0^2(1-\cos 2\beta)}{U_{y0}^2+U_0^2}. \tag{8}$$

For further simplification let us take advantage of the small value of angle β in the near-balance condition and neglect quantities of the second order in the series

$$\cos 2\beta=1-\frac{4\beta^2}{2}\ldots=1-2\beta^2. \tag{9}$$

Combining (6), (8) and (9) we obtain

$$A=\frac{\beta U_{y0}U_0}{\sqrt{U_{y0}^2+U_0^2}} \tag{10}$$

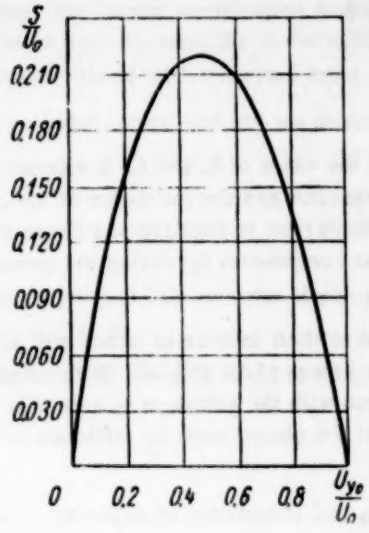


Fig. 3.

From the vector diagram of Fig. 2 it is possible to substitute angle β by the phase difference $\varphi = \varphi_1 = \varphi_0$, and write, considering the smallness of angles φ and β

$$A = \frac{\varphi U_{10} U_{y0}}{\sqrt{U_{y0}^2 + U_0^2}}. \tag{11}$$

Let us determine the sensitivity S as the degree to which value of the small semiaxis of the ellipse depends on the phase difference φ:

$$S = \left(\frac{\partial A}{\partial \varphi}\right)_{\substack{U_0 = \text{const} \\ \varphi \to 0}} = U_0 \frac{\frac{U_{y0}}{U_0}\left(1 - \frac{U_{y0}}{U_0}\right)}{\sqrt{1 + \left(\frac{U_{y0}}{U_0}\right)^2}} \tag{12}$$

Figure 3 represents a graphic form the relation

$$\frac{S}{U_0} = f\left(\frac{U_{y0}}{U_0}\right).$$

For a given U_0 the maximum sensitivity (at the condition of balance) is attained when

$$0.45 < \frac{U_{y0}}{U_0} < 0.46. \tag{13}$$

In practice it is sufficient to take $U_{y0} \approx 0.5U_0 = U_{10}$, which is equivalent to

$$R_1^2 + \frac{1}{\omega^2 C_1^2} = R_0^2 + \frac{1}{\omega^2 C_0^2}. \tag{14}$$

Solving (14) in conjunction with phase-balance condition

$$\omega R_1 C_1 = \omega R_0 C_0 \quad (\operatorname{tg}\delta_1 = \operatorname{tg}\delta_0), \tag{15}$$

we obtain the approximate condition for maximum sensitivity

$$C_1 = C_0, \; R_1 = R_0. \tag{16}$$

Special remarks. By using in the Fig. 1 circuit a reference capacitor C_0 and a reference resistance box R_0 it becomes possible to determine the tangent of the loss angle by the deviations ΔR and ΔC from certain values of R_0 and C_0 instead of reading it directly. Then

$$\operatorname{tg}\delta_1 = \omega R_1 C_1 = \omega R_0 C_0 = \omega(R_0 - \Delta R')(C_0 + \Delta C') = \\ = \omega(R_0 + \Delta R'')(C_0 - \Delta C''),$$

whence,

$$\operatorname{tg}\delta = \omega \Delta R \Delta C'' \frac{\left(1+\frac{\Delta R'}{\Delta R''}\right)\left(1+\frac{\Delta C''}{\Delta C'}\right)}{\left(1-\frac{\Delta R'}{\Delta R''}\cdot\frac{\Delta C''}{\Delta C'}\right)^2}. \quad (17)$$

Thus (similarly to the substitution method) the error in determining the value of R_0 and C_0 is eliminated making the measurement independent of the initial capacitance of the capacitor and the resistance of the connecting leads. This method assumes, of course, the constancy of the stray currents (due to resistive and capacitive leakages, and currents through the capacitances shunting the resistance-box components R_0) during the measurement.

A complete stability of stray currents is theoretically impossible due to their inconstant nature and also due to the variation of the voltage across the circuit when it is changed by the values of ΔR and ΔC. If the duration of measurements is small and the deviations ΔR and ΔC are small compared with the values of R_0 and C_0 it is possible to consider the stray current as almost constant. The sensitivity of the circuit must be sufficient to allow small variations ΔR and ΔC of the circuit.

If the operating frequency is raised the reactance of the resistance R_0 and inductance of capacitor C_0 must be taken into account in the basic formula $\operatorname{tg}\ \delta_1 = \omega R_0 C_0$.

LITERATURE CITED

[1] C. B. Sawyer and C. N. Tower, Phys. Rev. 1930, 85, 269.

[2] A. L. Khodakov, Bulletin of the Acad. Sci. USSR, Physical Series, 12 (1958).

EFFECT OF THE COIL INDUCTANCE ON THE FREQUENCY ERROR OF RECTIFYING INSTRUMENTS

E. N. Kurilov and M. N. Drogomyzhskaya

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 25-29, March, 1960

The frequency error of rectifying instruments was analyzed in a number of papers (for instance [1, 2, 3])

The majority of the analyses are based, due to the complexity of phenomena, on certain approximations. Thus in [2] the inductance of the measuring coil is not taken into account, in [3] the analysis is made on the basis of equivalent circuits without considering the switching process due to the inductance of the coil.

In this article one of the components of the frequency error is analyzed for full and half-wave rectifiers, a component due only to the inductance of the coil.

Let us start the analysis of this error in a half-wave rectifier (Fig. 1) when it is working into an inductive impedance.

In order to find the dc component of the current I_L in the inductance let us use the expression given in [4]:

$$I_L = \frac{U_m}{\pi} \sin\frac{\psi}{2}\left[(\kappa'' g'' - \kappa' g')\sin\left(\frac{\psi}{2}+\varphi\right) + (\kappa'' g'' m' - \kappa' g' m'')\cos\left(\frac{\psi}{2}+\varphi\right)\right]. \quad (1)$$

where ψ is the angle which determines the duration of the rectifier's operating condition; φ is the angle which determines the instant rectification begins; k' and k" are transfer constants of the quadripole (Fig. 1b) in an unloaded state with the rectifier in the nonoperating and operating condition; g' and g" are the output conductances of the quadripole M with a shorted input and corresponding to the same conditions on the rectifier.

The values of m' and m" are determined from the equality

$$m' = \omega g' L,$$
$$m'' = \omega g'' L$$

In deriving (1) a piecewise linear approximation of the voltampere characteristic of the rectifier was used, as shown in Fig. 2a.

For the circuit under consideration

$$\kappa' = \kappa'' = 1,$$
$$g' = \frac{1}{r_w + r}, \quad g'' = \frac{1}{r_f + r}. \tag{2}$$

Substituting in (1) the equalities (2) we have

$$I_L = \frac{U_m}{\pi}(g'' - g') \sin\frac{\psi}{2} \sin\left(\frac{\psi}{2} + \varphi\right). \tag{3}$$

At a very low frequency ($\omega \to 0$) when it can be considered that the inductance does not affect the instant rectification begins, and $\psi = \pi$, and $\varphi = 0$ (for $u = U_m \sin\omega t$), the mean value of I_{LO} is determined by equation

$$I_{LO} = \frac{U_m}{\pi}(g'' - g'). \tag{4}$$

By definition the relative frequency error can be represented as

$$\Delta_f = \frac{I_L - I_{LO}}{I_{LO}},$$

or, taking into consideration (2), (3) and (4), as:

$$\Delta_f = \sin\frac{\psi}{2} \sin\left(\frac{\psi}{2} + \varphi\right) - 1. \tag{5}$$

The value of angle ψ with respect to m" for various values of m'/m" is given in [5].

It is easy to see that for a half-wave rectifier the frequency error is negative. In fact

$$\frac{m'}{m''} = \frac{r_f + r}{r_w + r}.$$

Here the denominator is considerably larger than the numerator. Hence it is not necessary to calculate the frequency error for various values of m'/m", and it is possible to assume that m'/m" = 0 or that m' = 0. Moreover the formula for calculating the frequency error can be reduced to the following form:

$$\Delta_f = \sin^2 \frac{\psi}{2} - 1. \qquad (6)$$

Figure 3 shows the relation of Δ_f to m" calculated from (6) and also points obtained experimentally. Tests were made with crystal diodes type D2E. A systematic deviation of the calculated from the experimental results for small values of m" is due to experimental and calculation errors and effects of auxiliary phenomena not examined in this article. On the whole the agreement between the calculated and the experimental values can be considered satisfactory.

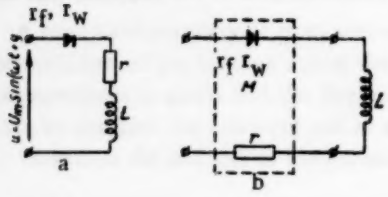


Fig. 1.

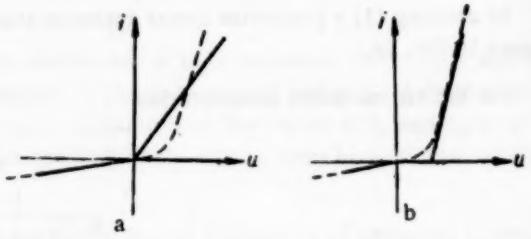


Fig. 2.

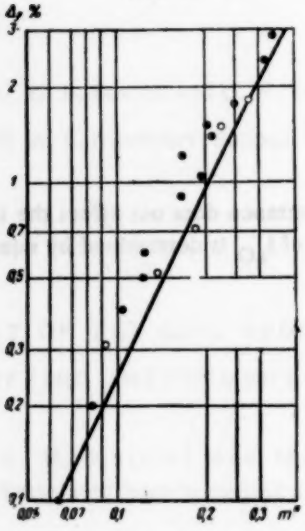


Fig. 3.

o) L=111 mh; r=618 ohms
o) L=50 mh; r=614 ohms
•) L= 25 mh; r=610 ohms

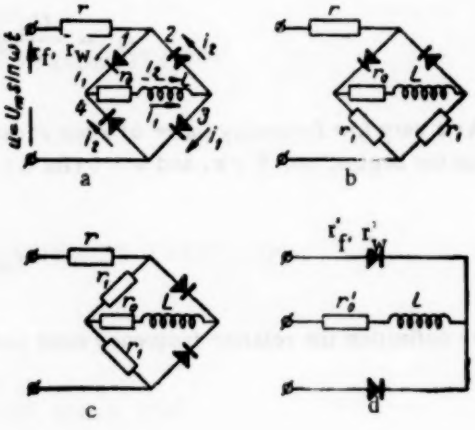


Fig. 4

The frequency error of a half-wave rectifier for m" < 0.4 can be approximated by the expression

$$\Delta_f = 19\,(m'')^2. \qquad (7)$$

The error of calculating by means of (7) does not exceed 20%.

Let us now examine errors of certain full-wave rectifiers (Fig. 4) which are most commonly used in measuring circuits [1].

All the relations for the first three circuits of Fig. 4 are similar and it is, therefore, possible to demonstrate the method of calculations on the example of the symmetrical bridge circuit (Fig. 4a).

The operation of the circuit can be divided into three conditions: condition I, when rectifiers 1 and 3 are conducting (the starting time is t_s and ending time t_e); condition II, when all the rectifiers are conducting (the starting time is t_e and ending time $\pi/\omega + t_s$); condition III, when rectifiers 2 and 4 are conducting (starting time is $\pi/\omega + t_s$ and ending time $\pi/\omega + t_e$).

Let us now derive current equations for each conditions of the circuit:

$$\text{I.} \qquad L\frac{dI_1}{dt}+(r_o+2r_f+r)I_1=E_m \sin \omega t, \tag{8}$$

$$\text{II.}\begin{cases} L\dfrac{d}{dt}(I_1+I_2)+(r_o+2r_f+r)I_1+(r_o-r)I_2=E_m \sin \omega t, & (9)\\ L\dfrac{d}{dt}(I_1+I_2)+(r_o-r)I_1+(r_o+2rf+r)I_2=-E_m \sin \omega t, & (10)\end{cases}$$

$$\text{III.} \quad L\frac{dI_2}{dt}+(r_o+2r_f+r)I_2=-E_m \sin \omega t. \tag{11}$$

Solving (8), (9), (10) and (11) we obtain

$$I_1=\frac{E_m}{r_o+2rf+r}\cos \varepsilon \sin(\omega t-\varepsilon)+A_1 e^{-\frac{t}{\tau}}, t_s<t<t_e \tag{12}$$

$$\begin{cases} I_1+I_2=Ae^{-\frac{t}{\tau_c}} \\ I_1-I_2=\dfrac{E_m}{r_f+r}\sin \omega t, \\ t_e<t<\dfrac{\pi}{\omega}+t_s ; \end{cases} \tag{13}$$

$$I_2=-\frac{E_m}{r_o+2rf+r}\cos \varepsilon \sin(\omega t-\varepsilon)+A_1 e^{\frac{\pi-\omega t}{\omega \tau}},$$

$$\frac{\pi}{\omega}+t_s<t<\frac{\pi}{\omega}+t_e \tag{14}$$

where

$$\tau=\frac{L}{r_o+2r_f+r}; \quad \operatorname{tg}\varepsilon=\omega\tau=m'; \quad \tau_c=\frac{L}{r_o+r_f}.$$

Using the uninterrupted property of the current through L and the fact that the transition of the rectifier from one state to the other occurs when the current is zero, we obtain from (12)-(14)

$$\sin(\psi+\varphi)=\sin \varphi e^{\frac{\pi-\psi}{m'}},$$

$$\sin(\psi+\varphi+\gamma)=\sin(\varphi+\gamma)e^{-\frac{\psi}{m'}}, \tag{15}$$

where

$$\psi=\omega(t_e-t_s); \quad \varphi=\omega t_s;$$

$$m''=\omega\tau_c=\frac{\omega L}{r_o+r_f}; \quad \gamma=\tan^{-1}\frac{m''-m'}{1+m'm''}.$$

By solving the simultaneous equations (15) it is possible to find the angles φ and ψ.

Finally the mean value of the current I_L in the measuring diagonal can be written as

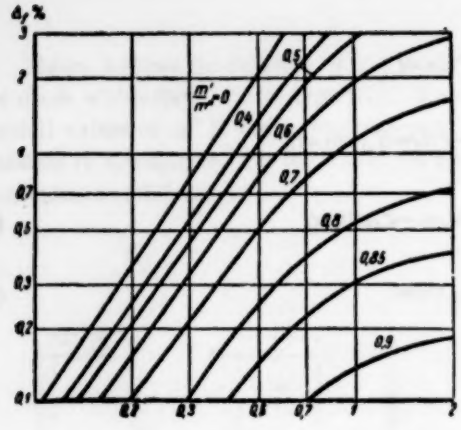


Fig. 5.

$$I_L = \frac{\omega}{\pi}\int_{t_S}^{t_e} i_1 \Big| dt + \frac{\omega}{\pi}\int_{t_e}^{t_S+\frac{\pi}{\omega}} (i_1+i_2) \Big| dt =$$

I II

$$= \frac{\omega}{\pi}\int_{t_S}^{t_e}\left[\frac{E_m}{r_0+2r_f+r}\cos\varphi\sin(\omega t-\varphi)+A_1 e^{-\frac{t}{\tau}}\right]dt +$$

$$+ \frac{\omega}{\pi}\int_{t_S}^{t_S+\frac{\pi}{\omega}} Ae^{-\frac{t}{\tau_c}}\,dt.*$$

After integration and certain transformations we obtain

$$I_L = \frac{2I_m}{\pi}\sin\frac{\psi}{2}\left[\sin\left(\frac{\psi}{2}+\varphi\right) + m''\cos\left(\frac{\psi}{2}+\varphi\right)\right]. \tag{16}$$

By using the above calculating technique for the other full-wave rectifying circuits shown in Fig. 4 it is possible to prove that for them equations (15) which determine the rectification angles and equation (16) which gives the mean value of current in the measuring device are of the same form as for the case derived above. The values of parameters m', m", m'/m" and I_m are given separately for each circuit in the table attached.

Let us note that the circuit (Fig. 4d) with the zero conductor [6] can also be easily reduced to a symmetrical bridge circuit (Fig. 4a) if it is assumed that

$$r_0' = r_0 + r,\ r_f' = 2r_f \text{ и } r_w' = 2r_w.$$

Let us now determine the frequency error of the full-wave rectifying circuits.

The mean value of the current in the measuring diagonal which does not contain a reactive component, will be, assuming a sinusoidal current and making the same approximation as before (of Fig. 2a), equal to

$$I_{L0} = \frac{2}{\pi} I_m. \tag{17}$$

Here the frequency error will, if (16) and (17) are taken into consideration, assume the form

$$\Delta_f = \sin\frac{\psi}{2}\left[\sin\left(\frac{\psi}{2}+\varphi\right) + m''\cos\left(\frac{\psi}{2}+\varphi\right)\right] - 1. \tag{18}$$

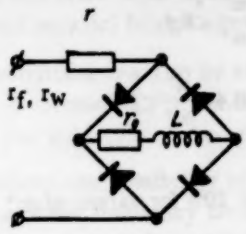
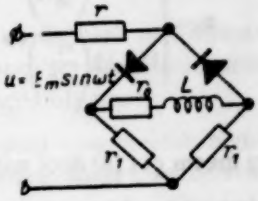
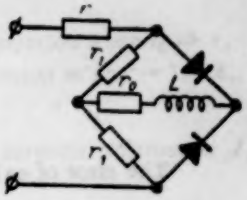
Calculations have shown that the first term of equation (18) is always larger than 1. Thus, the frequency error due to the induction of the coil is positive for all the full-wave rectifying circuits.

Figure 5 provides a relation of Δ_f to m" calculated on the basis of (18).

Since it is not always convenient to use graphs for determining the frequency error we also provide approximate formulas for this purpose:

$$\Delta_f = a_n (m'')^2,$$

* Here subscripts I and II denote currents for the corresponding conditions of the circuit.

Parameter \ Circuit			
m'	$\frac{\omega L}{r_o+2r_f+r} = \frac{Q}{1+2\alpha+\beta}$	$\frac{\omega L}{r_o+r_1\left(1+\frac{r_f+r}{r_f+r_1+r}\right)} = \frac{Q}{1+\gamma\left(1+\frac{\alpha+\beta}{\alpha+\beta+\gamma}\right)}$	$\frac{\omega L}{r_o+r_f+r_1\frac{r_1+r}{2r_1+r}} = \frac{Q}{1+\alpha+\gamma\frac{\beta+\gamma}{\beta+2\gamma}}$
m''	$\frac{\omega L}{r_o+r_f} = \frac{Q}{1+\alpha}$	$\frac{\omega L}{r_o+2\frac{r_f r_1}{r_f+r_1}} = \frac{Q}{1+2\frac{\alpha\gamma}{\alpha+\gamma}}$	$\frac{2\omega L}{2r_o+r_f+r_1} = \frac{Q}{1+\frac{1}{2}(\alpha+\gamma)}$
I_m	$\frac{E_m}{r_o+2r_f+r}$	$\frac{r_1 E_m}{(r_o+r_1)(r_f+r_1+r)+r_1(r_f+r)}$	$\frac{r_1 E_m}{(2r_1+r)(r_o+r_f)+r_1(r_1+r)}$
$\frac{m'}{m''}$	$1-\frac{r_f+r}{r_o+2r_f+r} = \frac{1+\alpha}{1+2\alpha+\beta}$	$\frac{r_o+2\frac{r_f}{r_f+r_1}r_1}{r_f+\frac{1}{2}r_1+r} \Big/ \frac{r_o+2\frac{r_f}{r_f+r_1+r}}{} = \frac{1+\frac{2\alpha\gamma}{\alpha+\gamma}}{1+\gamma\left(1+\frac{\alpha+\beta}{\alpha+\beta+\gamma}\right)}$	$\frac{2r_o+r_f+r_1}{2\left(r_o+r_f+r_1\frac{r_1+r}{2r_1+r}\right)} = \frac{1+\frac{1}{2}(\alpha+\gamma)}{1+\alpha+\gamma\frac{\beta+\gamma}{\beta+2\gamma}}$

where $Q=\frac{\omega L}{r_o}$

where

$$a_n=\begin{cases}8-13\left(\dfrac{m'}{m''}\right)^2 & \text{—for } \dfrac{m'}{m''}<0.4,\\ 11-12\left(\dfrac{m'}{m''}\right)^{0.8} & \text{— for } 0.4<\dfrac{m'}{m''}<0.8.\end{cases} \tag{19}$$

The error of calculating by means of (19) does not exceed 20% for values of $m'' < 0.85$.

Let us note that the error rises with a decreasing value of ratio m'/m'' (Fig. 5).

For a further analysis let us introduce dimensionless quantities

$$\alpha=\frac{rf}{r_0},\ \beta=\frac{r}{r_0};\quad \gamma=\frac{r_1}{r_0}.$$

It will be seen from the table that the smallest value of ratio m'/m'' and hence the largest error Δ_f occur for $\beta \neq 0$. Therefore we shall analyze the error only for the most unfavorable case, of a given current (in voltmeter circuits usually for small voltages $r \gg r_0$).

a) A symmetrical bridge circuit (Fig. 4a). From (19) we have for $m'/m'' < 0.4$

$$\Delta_f=Q^2\left[\frac{8}{(1+\alpha)^2}-\frac{13}{(1+2\alpha+\beta)^2}\right]$$

or taking $\beta \gg \alpha$ and $\beta \gg 1$,

$$\Delta_f=8Q^2\frac{1}{(1+\alpha)^2}. \tag{20}$$

It will be seen from (20) that for voltmeter circuits with a relatively large multiplying resistance r the error does not depend on parameter m' (see table), i.e., it does not depend on the circuit time constant when the rectifiers 1,3 or 2,4 are conducting (Fig. 4a).

Moreover it is possible to conclude from (20) that in order to decrease the effect of the coil inductance on the frequency error, it is advisable to select, in a symmetrical bridge circuit, rectifiers with a large forward resistance r_f as compared with the resistance of the coil r_0 or increase the rectifiers forward resistance artificially (by connecting additional resistances in all the rectifier arms of the bridge).

b) A parallel bridge circuit (Fig. 4b). For this circuit when $\beta \to \infty$

$$\frac{m'}{m''}=1-2\frac{1}{\left(1+\frac{\alpha}{\gamma}\right)\left(2+\frac{1}{\gamma}\right)}. \tag{21}$$

Hence, in order to obtain a larger ratio $m'\ m''$ it is necessary to strive for a large $\alpha = r_f/r_0$ and a small $\gamma = r_1/r_0$.

c) A series bridge circuit (Fig. 4c). For this circuit when $\beta \to \infty$

$$\frac{m'}{m''}=1-\frac{1}{2}\frac{1}{1+\frac{1}{\alpha+\gamma}} \tag{22}$$

It will be seen from (22) that the ratio will be large with small values of α and γ.

It will be seen that for the last two circuits the ratio m'/m'' is a finite quantity not equal to zero. For the symmetrical bridge circuit this ratio tends to zero for large values of β. Hence, a smaller frequency error is to be expected in the series and parallel bridge circuits.

A specified current condition can also be attained on the basis of temperature compensation when $r_0 \gg r$, for instance, in high-voltage voltmeters [7]. In this instance for the circuits under consideration $m'/m'' \to 1$, i.e., the frequency error due to the induction of the coil is negligibly small.

This conclusion confirms the possibility of developing commercial high-precision detector voltmeters / [7] from the point of view of the frequency error component under consideration.

In conclusion let us note that a better approximation of the voltampere characteristic is achieved by taking a piecewise linear curve which does not pass through the origin of the coordinates (Fig. 2b). Since the difference between the mean value of the currents in the circuit with reaction and in an ideal one (without reaction) is taken for calculating the frequency error, the values of the frequency error obtained by means of the above mentioned or the actually used approximation will be practically the same. These considerations confirm the test shown in Fig. 3. The use of the approximation shown in Fig. 2b would have complicated the calculations considerably.

CONCLUSIONS

The conclusions arrived at in this article (together with power, temperature compensation, sensitivity and other considerations) can serve for obtaining a more reasonable selection of parameters for rectifying instruments and their circuit.

LITERATURE CITED

[1] K. B. Karandeev, Semiconductor Rectifiers in Measurement Techniques, [in Russian] (Acad. Sci. Ukr. SSR Press, Kiev, 1954).

[2] L. Cremer, Arch. für Elektr., 1932, Vol. 26.

[3] H. Grave, Arch. für Elektr., 1940, Vol. 34, page 2.

[4] V. P. Sigorskii and L. A. Sinitskii, Élektrichestvo, No. 4, 1958.

[5] I. L. Kaganov, Electronic and Ionic Converters [in Russian] (v. 1 Gosénergoizdat, 1952).

[6] É. N. Dolbnev, "Certain possibilities in temperature compensation of detector voltmeters," Proceeding of the Conference on the "Application of Semiconductors in Instrument Making" [in Russian] (Mashgiz, 1958).

DESIGN OF DAMPING SPRINGS FOR TORSION-SUSPENSION INSTRUMENTS

P. I. Khrenkov

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 30-31, March, 1960

In designing torsion-suspension instruments it is necessary to know the strain in the springs by means of which the required stress is produced and the limit up to which the spring may be loaded.

The counteracting moment in a torsion suspension is determined from the formula

$$W = \frac{1}{3} bh^3 \frac{G}{l} + \frac{1}{12} b^3 h \frac{\delta}{l} + \frac{1}{360} b^5 h \frac{E\alpha^2}{l^3}, \quad (1)$$

where l is the length of the suspension; b is the width of the strip; h is the thickness of the strip; G is the modulus of rigidity; E is the elastic modulus; α is the angle of twist.

It will be seen from (1) that the length of the suspension affects the counteracting moment. Without knowing what deflection the spring will receive it is impossible to determine the actual length of the suspension. In certain instances the deflection may reach 1.5 mm (within the limits of elasticity) which amounts to 15% of the suspension's length of 10 mm.

Since 1957 the "Vibrator" plant produces instruments with a damping spring shown in Fig. 1. These springs are better designed than those previously used, since their center is scarcely displaced with respect to the line of symmetry (this is of considerable importance), and it is more stable in the plane perpendicular to the suspension.

In deriving a formula for the deflection of such a spring we shall assume that the deformations of its various portions are small as compared with their sizes. It is also assumed that the end of the spring to which the suspension is soldered is not strained.

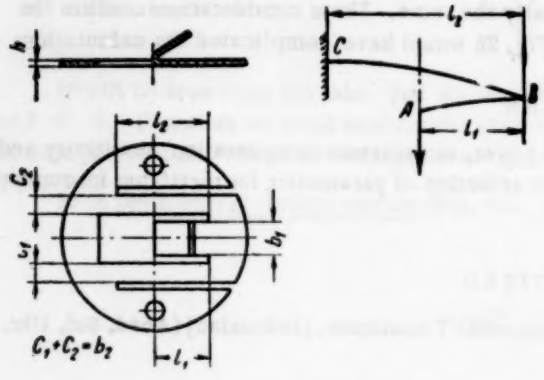


Fig. 1.

The total deformation of the spring at point C (Fig. 1) can be considered as the sum of the deformation of part AB, which is an independent cantilever beam with its rigidly connected end at point B and the deformation of part BC.

The deflection of point A under the action of force P will be

$$f_1=\frac{Pl^3}{3EG_1}. \tag{2}$$

At the connecting point B a reaction will arise equal in value but opposite in direction to the applied force P, and an a clockwise moment M:

$$M=Pl_1. \tag{3}$$

Beam CB is affected by force P acting downwards and an anticlockwise moment.

The deflection and the angle of rotation of the cross section at point B under the effect of force P will be, respectively,

$$f_2=\frac{Pl_2^3}{3EG_2} \tag{4}$$

$$\theta=\frac{Pl_2^2}{2EG_2} \tag{5}$$

Under the effect of moment M the deflection and angle of rotation at point B will be

$$f_3=\frac{Ml_2^2}{2EG_2}=-\frac{Pl_1l_2^2}{2EG_2}; \tag{6}$$

$$\theta_2=\frac{Ml_2}{EG_2}=\frac{Pl_1l_2}{EG_2}. \tag{7}$$

The value of the additional displacement of point A due to the deformation at point B can be calculated from (5) and (7) as

$$f_4=l_1\theta_1=l_1\left(-\frac{Pl_2^2}{2EG_2}\right); \tag{8}$$

$$f_3 = l_1\theta_3 = l_1\left(\frac{Pl_1l_2}{EG_2}\right). \tag{9}$$

The total deformation of the spring is determined as the sum of the deformations of its parts:

$$f = f_1 + f_2 + f_3 + f_4 + f_5. \tag{10}$$

In substituting the corresponding values we obtain

$$f = \frac{4P}{Eh^3}\left(\frac{l_1^3}{b_1} + \frac{l_2^3 - 3l_1l_2^2 + 3l_1^2l_2}{b_2}\right). \tag{11}$$

In order to evaluate the effect of the assumptions formula (11) was checked experimentally. This check showed the necessity of introducing a correction factor K whose value with respect to the thickness of the spring is shown in Fig. 2.

The final design formula has the form

$$f = K\frac{4P}{Eh^3}\left(\frac{l_1^3}{b_1} + \frac{l_2^3 - 3l_1l_2^2 + 3l_1^2l_2}{b_2}\right). \tag{12}$$

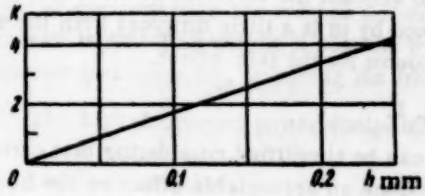


Fig. 2.

For the convenience of manufacture the configuration of the spring and its size remain constant and only its thickness changes for different loads in order to keep the deflection within the elastic limits.

In calculations it is necessary to consider the dynamic loading, by substituting P in (12) by the sum $P_1 + P_2$, where P_1 is the static and P_2 the dynamic loading obtained from

$$P_2 = ma, \tag{13}$$

where $m = G/g$ is the mass of the moving parts, a is the acceleration in fractions of g and G is the weight of the moving parts.

INVESTIGATION OF A HIGH-FREQUENCY THERMISTOR VOLTAGE METER

A. M. Fedorov and B. E. Rabinovich

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 31-33, March, 1960

In order to determine the frequency characteristic of a standard compensated voltmeter [1] at 0.1 to 1 v it was compared with a thermistor meter consisting of a balanced bridge circuit [2]. This method of obtaining a frequency characteristic can be used with other types of voltmeters as well.

The thermistor is inserted into a special coaxial device which ensures a parallel connection of the voltmeter probe diode and the thermistor.

The thermistor voltage meter has a systematic frequency error due to the reactive impedance of the thermistor. In order to determine this error it is necessary to know the thermistor's equivalent circuit when it is connected to the thermistor-diode measuring probe. In this article the equivalent circuit is analyzed and the technique of determining the parameters of this circuit is outlined.

The thermosensitive element consisted in these experiments of a thermistor type TSh-2B which has, according to our experience the best reproducibility of readings as compared with thermistors of other types.

The well-known thermistor equivalent circuit [3] does not take into account the variation of the thermistor wire resistance due to skin effect. Therefore the equivalent circuit adopted by us is a little different from the one mentioned above by the incorporation in it of component ΔR_2 which accounts for the skin effect.

The equivalent circuit of a diode-thermistor probe is shown in Fig. 1.

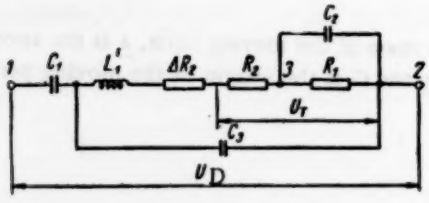


Fig. 1. C_1) Capacity of the blocking capacitor L_1') inductance of the thermistor lead-out wires; R_1) dc resistance of the thermistor bead; C_2) capacitance due to the bead semiconductor material; C_3) capacitance of the shell dielectric and the thermistor leads; R_2) resistance of the thermistor leads; ΔR_2) increase in the effective resistance of the thermistor leads due to skin effect; U_D) voltage at the input to the voltmeter; and U_T) voltage at the thermistor bead.

This circuit can be simplified, considering that certain elements do not produce an appreciable effect on the frequency error of the thermistor. For instance capacitance C_3 measured by means of an interelectrode capacity-measuring set was found to be 0.02-0.03 $\mu\mu$f, whereas capacitance C_1 is 150 $\mu\mu$f. Hence, the maximum error due to C_3 in measuring the thermistor voltage will occur when $C_2 \to 0$ and $R_1 \to \infty$ and will be

$$\Delta_0 \max = \frac{C_3}{C_1} \cdot 100 = \frac{0.03}{150} \cdot 100 = 0.02\%. \qquad (1)$$

Thus in practice capacitance C_3 will only present an additional load to the generator and it can be neglected.

Similarly the rise in the thermistor resistance ΔR_2 due to skin effect produces, according to calculations, an error in the voltage measurement not exceeding 0.15% under the worst conditions. Hence, in further calculations this effect is neglected.

For an experimental determination of L_1' and C_2 let us assume that in the first approximation, resistance R_2 is concentrated in the thermistor bead. For $R_2 \ll R_1$ and $R_2 \ll x_1 = \omega L_1' - 1/\omega C_1$ this assumption hardly reduces

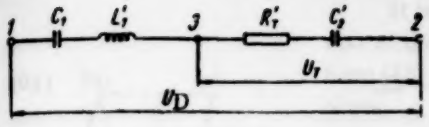


Fig. 2.

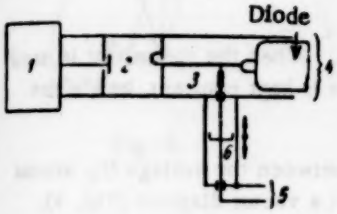


Fig. 3. 1) Generator; 2) filter; 3) thermistor; 4) voltmeter measuring probe; 5) leads to the thermistor bridges; 6) shorted coaxial line.

the accuracy of determining L_1' and C_2. Now the equivalent circuit of the diode-thermistor probe can be converted into an equivalent series circuit (Fig. 2).

The impedance of the circuit is

$$z = R_T' + jx_1 - jx_2', \tag{2}$$

also

$$R_T' = \frac{R_T}{1 + R_T^2 \omega^2 C_2^2}, \tag{3}$$

$$x_1 = \omega L_1' - \frac{1}{\omega C_1}, \tag{4}$$

$$x_2' = \frac{R_T^2 \omega C_2}{1 + R_T^2 \omega^2 C_2^2}. \tag{5}$$

If in series with this circuit (Fig. 2) an additional reactance x_a is connected and made of such a value and sign that

$$jx_1 - jx_2' + jx_a = 0$$

the circuit impedance will become purely resistive and equal to R'_T. Such a compensation of a reactive impedance can be attained at high frequencies by using in series with the thermistor a shorted coaxial line whose length is varied by means of a sliding plunger (Fig. 3). Compensation of the reactance is attained by placing the plunger in a position which provides a minimum reading on the compensated reference voltmeter. It is obvious that at the instant of compensation the voltage across the equivalent thermistor resistance R'_T will be equal to that at the voltmeter input. This makes it possible to determine the value of capacitance C_2 by varying the value of the thermistor resistance R_T, providing the frequency and the voltage at the voltmeter remains constant.

The high-frequency power dissipated at the thermistor is equal to

$$P = \frac{U_T^2}{R_T} = \frac{U_D^2}{R_T'}. \tag{6}$$

It follows from (6) that

$$U_D^2 = U_T^2 \frac{R_T'}{R_T}. \tag{7}$$

If the frequency and voltage at the input of the voltmeter are maintained at a constant value, and the dc resistance of the thermistor is varied from R_{T1} to R_{T2} and the voltage is measured for each of these resistances by means of the thermistor meter, we shall obtain the equality

$$U_{T1}^2 \frac{R_{T1}'}{R_{T1}} = U_{T2}^2 \frac{R_{T2}'}{R_{T2}}. \tag{8}$$

Substituting (3) in (8) and solving for C_2 we have

$$C_2 = \frac{1}{\omega} \sqrt{\frac{U_{T2}^2 - U_{T1}^2}{U_{T1}^2 R_{T2}^2 - U_{T2}^2 R_{T1}^2}}. \tag{9}$$

Formulas (3), (4), (5) and (9) have been derived without taking C_3 into consideration. A more complicated analysis which, owing to its size, is not given here shows that the actual value of C_2 is

$$C_2=\frac{1}{\omega}\sqrt{\frac{(U_{\tau 2}^2-U_{\tau 1}^2)(1-2\omega^2 L_1' C_3)}{U_{\tau 1}^2 R_{\tau 2}^2-U_{\tau 2}^2 R_{\tau 1}^2}}-C_3. \tag{10}$$

The values of capacitance C_2 were determined at 200 to 1000 Mc. The thermistor resistance was varied between 200 ± 50 ohms. The capacitance values thus obtained for a thermistor with an operating resistance of 200 ohms are given in the table below.

The value of C_2 depends on the thermistor operating resistance and frequency. When the thermistor is used for voltage measurements, however, the frequency is set and the operating resistance is kept constant, hence the value of C_2 remains constant.

Let us return to the equivalent circuit of the probe and examine the relation between the voltage U_T across the thermistor and voltage U_D across the voltmeter. For this purpose let us construct a vector diagram (Fig. 4).

It follows from the diagram that

$$U_D=\sqrt{U_\tau^2\cos^2\alpha+(x_1 I-U_\tau\sin\alpha)^2}. \tag{11}$$

After transformation we obtain

$$U_D=U_\tau\sqrt{1-2\frac{x_1}{x_2}+\frac{x_1^2}{x_2^2}+\frac{x_1^2}{R_\tau^2}} \tag{12}$$

where

$$x_1=\omega L_1'-\frac{1}{\omega C_1}, \tag{13}$$

$$x_2=\frac{1}{\omega C_2}. \tag{14}$$

Equation (12) can be used for determining the value of x_1 by means of varying the thermistor resistance. If at a constant frequency and voltage U_D across the voltmeter, the dc thermistor resistance is varied and the voltage U_T across the thermistor is measured at the same time by means of the thermistor meter, the following equality must hold:

$$U_{\tau 1}^2\left(1-2\frac{x_1}{x_2}+\frac{x_1^2}{x_2^2}+\frac{x_1^2}{R_{\tau 1}^2}\right)=U_{\tau 2}^2\left(1-2\frac{x_1}{x_2}+\frac{x_1^2}{x_2^2}+\frac{x_1^2}{R_{\tau 2}^2}\right). \tag{15}$$

Solving (15) with respect to x_1 we have

$$x_1=B\pm\sqrt{B^2-Bx_2}, \tag{16}$$

where

$$B=\frac{(U_{\tau 2}^2-U_{\tau 1}^2)x_2 R_{\tau 1}^2 R_{\tau 2}^2}{\left[U_{\tau 2}^2 R_{\tau 1}^2(R_{\tau 2}^2+x_2^2)-U_{\tau 1}^2 R_{\tau 2}^2(R_{\tau 1}^2+x_2^2)\right]}. \tag{17}$$

The value of the blocking capacitance C_1 as it was previously pointed out amounts to 150 μμf. Hence, there only remains L_1' to be determined.

It is easier to determine L_1' at high frequencies where its reactance is high and that of the blocking capacitance is small. We determined, therefore, inductance L_1' from (13) and (16) at 900 Mc by varying the thermistor resistance between 200 ± 25 ohms.

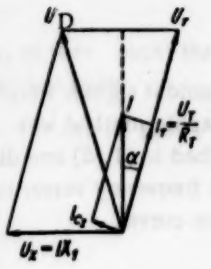


Fig. 4.

For the thermistor under investigation placed in the thermistor-diode probe, inductance L_1' amounted to $(0.99 \pm 0.02) \cdot 10^{-8}$ h.

Thus we have all the required data for calculating the frequency correction of a thermistor voltage meter and determining the actual voltage at the voltmeter input:

$$U_D = U_T \left(1 + \frac{\Delta_{ox}}{100}\right), \tag{18}$$

where

$$\Delta_{ox} = \left(\sqrt{1 - 2\frac{x_1}{x_2} + \frac{x_1^2}{x_2^2} + \frac{x_1^2}{R_T^2}} - 1\right) \cdot 100\%. \tag{19}$$

The table shows calculated corrections for the type TSh-2B thermistor under consideration with R_T = 200 ohms, $L_1' = 0.99 \cdot 10^{-8}$h, and C_1 = 150 μμf.

	Mc	200	400	600	800	1000
C_1	μμf	0.38	0.32	0.27	0.23	0.20
Δ_{ox}	%	−0.3	−1.2	−2.0	−2.6	−2.8

The determination of the parameters of a thermistor equivalent circuit was checked by comparing the readings of a reference compensated voltmeter with those of a bolometric voltage meter, which had as a sensitive element, a wire bolometer included in the same thermistor-diode probe. At frequencies up to 900 Mc the readings of the two voltage-measuring devices (after frequency corrections were applied) did not differ by more than 1% for the same voltmeter reading.

LITERATURE CITED

[1] B. E. Rabinovich and A. M. Fedorov, Izmeritel'naya Tekhnika, No. 2, 1958.*

[2] A. M. Fedorov and B. E. Rabinovich, Proceedings of the VNIIM, v. 40, (100) 1959.

[3] R. A. Valitov and V. N. Sretenskii, Radio Measurements at Ultrahigh Frequencies [in Russian] (Voenizdat, 1958).

*[see English translation].

AN OSCILLOGRAPHIC METHOD OF MEASURING FREQUENCY DEVIATION OF FREQUENCY-MODULATED SIGNALS

P. A. Shpan'on and N. B. Petrov

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 34-37, March, 1960

When various methods of measuring frequency deviation of frequency-modulated sinusoidal signals were studied at the Khar'kov State Institute of Measures and Measuring Instruments, the oscillographic method was included. This method is a version of the instantaneous frequency-measuring method described in [1, 2] and differs from the latter in using an asymmetrical oscillogram peculiar to the extremal values of the frequency versus time function instead of the symmetrical one, obtained near the bend of the frequency versus time curve.

The frequency-modulated voltage $u=U_{m_1}\sin\left(\omega t+\frac{\Delta\omega}{\Omega}\sin\Omega t+\alpha\right)$ is mixed with the "search" voltage $u=U_{m_2}\cos\omega_0 t$ (here $\omega/2\pi$ is the mean frequency of the frequency-modulated voltage; $\Omega/2\pi$ is the modulating frequency; α is an arbitrary phase, and $\omega_0/2\pi$ is the "search" frequency).

The mixing of these frequencies produces a difference-frequency component

$$u(t)=U_m\sin\left[(\omega-\omega_0)\,t+\frac{\Delta\omega}{\Omega}\sin\Omega t+\alpha\right]. \tag{1}$$

The "search" frequency may be outside or inside the swing of the frequency-modulated voltage.

Let us examine in detail the border case when $(\omega-\omega_0)=\Delta\omega$; and $\cos\Omega t=1$, i.e., when $t=\pi/\Omega$. The instantaneous frequency at that point will equal zero, and the voltage U(t) will remain constant in its vicinity. Let us now examine at that point the function represented by (1). The voltage has the form

$$u\left(\frac{\pi}{\Omega}\right)=U_m\sin\left[(\omega-\omega_0)\frac{\pi}{\Omega}+\alpha\right] \tag{2}$$

or

$$u\left(\frac{\pi}{\Omega}\right)=U_m\sin\left(\frac{\Delta\omega}{\Omega}\pi+\alpha\right) \tag{3}$$

For

$$0<\frac{\Delta\omega}{\Omega}\pi+\alpha<\pi \text{ we get } U\left(\frac{\pi}{\Omega}\right)>0;$$

and for

$$\pi<\frac{\Delta\omega}{\Omega}\pi+\alpha<2\pi \text{ we get } U\left(\frac{\pi}{\Omega}\right)<0.$$

The derivative of function U(t) is

$$\frac{dU}{dt}=U_m\cos\left[(\omega-\omega_0)\,t+\frac{\Delta\omega}{\Omega}\sin\Omega t+\alpha\right]\left[(\omega-\omega_0)+\Delta\omega\cos\Omega t\right]. \tag{4}$$

Then,

$$\frac{dU}{dt}\left(\frac{\pi}{\Omega}\right)=0, \tag{4'}$$

i.e., at that point the curve is parallel to the T axis and there is a characteristic horizontal stretch of the curve near that point.

It can be shown that

$$\frac{d^2u}{dt^2}\left(\frac{\pi}{\Omega}\right)=0 \tag{5}$$

and that

$$\frac{d^3u}{dt^3}\left(\frac{\pi}{\Omega}\right)=U_m\cos\left(\frac{\Delta\omega}{\Omega}\pi+\alpha\right)\Delta\omega\,\Omega^2\neq 0. \tag{6}$$

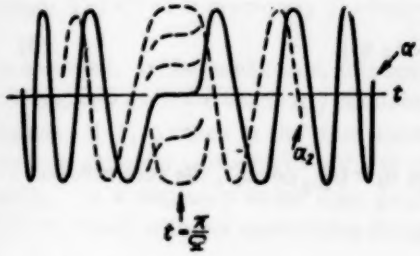


Fig. 1.

Thus at $t=\pi/\Omega$ the function has a point of inflection. Also $\frac{d^3u}{dt^3}=0$ for $\left(\frac{\Delta\omega}{\Omega}\pi+\alpha\right)=\pi/2$ and for $t=\pi/\Omega$, i.e., for the value of the phase when $u=U_m$. For these values there exists a maximum of a higher order.

In examining the voltage u(t) to the left and the right of $t=\pi/\Omega$, i.e., for $t=\pi/\Omega\pm\tau$, it is possible to show that for the voltage is larger for $\tau<0$, than for $\tau<0$.

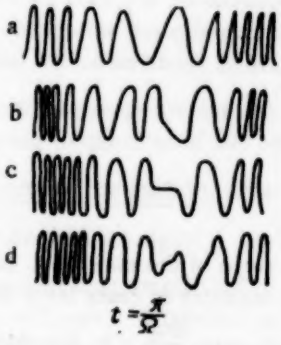


Fig. 2.

For $\left(\frac{\pi\Delta\omega}{\Omega}+\alpha\right)>\frac{\pi}{2}$ the reverse relation holds. The family of curves in the vicinity of point $t=\frac{\pi}{2}$ is shown in Fig. 1.

Thus the characteristic property of the function under consideration for $t=\frac{\pi}{\omega}$ and $\omega-\omega_0=\Delta\omega$ consists in horizontal stretches of the function curve situated at different levels according to the value of α.

If the voltage represented in (1) is fed to the vertical deflecting plates of the oscilloscope and modulating voltage $U_\Omega\cos\Omega t$ to the horizontal plates the following pattern will be observed:

a) when $\omega_0>\omega+\Delta\omega$, i.e., when ω_0 is outside the frequency swing. In this case a characteristic frequency modulated curve is observed. Since function $\sin\left[(\omega-\omega_0)t+\frac{\Delta\omega}{\Omega}\sin\Omega t+\alpha\right]$ is not periodic, the scanning by means of frequency $F=\Omega/2\pi$ produces a moving curve (Fig. 2a);

b) when ω_0 is near to $\omega+\Delta\omega$. A bend appears at point $t=\pi/\Omega$ (Fig. 2b);

c) when $\omega_0-\omega=\Delta\omega$. In this case Fig. 2b changes to Fig. 2c with its characteristic horizontal stretch in the vicinity of point $t=\pi/\Omega$, a stretch whose distance from the horizontal axis is equal to $U_m\sin(\pi\Delta\omega/\Omega+\alpha)$, i.e., depends on the value of α.

d) when $(\omega_0-\omega)< \Delta\omega$. With the variation of ω_0 within the frequency swing range, Fig. 2c changes to Fig. 2d and then near to $t = \frac{\pi}{2\Omega}$, i.e., for $\omega_0 = \omega$ it changes to the characteristic shape used for measurements of the instantaneous frequency in [1].

e) when $\Delta\omega = \omega-\omega_0$. The characteristic horizontal stretch appears at the other end of the oscillogram at point $t = -\frac{\pi}{\Omega}$. Let the values of ω_0 corresponding to points "c" and "e" be ω_{01} and ω_{02}. By measuring frequencies $f_{01} = \omega_{01}/2\pi$ and $f_{02} = \omega_{02}/2\pi$ it is possible to determine with a symmetrical, and in this particular case, sinusoidal frequency modulation, the frequency deviation from the formula

$$\Delta f=\frac{1}{2}(f_{01}-f_{02}). \tag{7}$$

Let us now examine the effect of stray amplitude modulation. In this case the voltage has the form

$$u_1= U_{m_1} \sin\left(\omega t+\frac{\Delta\omega}{\Omega}\sin\Omega t+\alpha\right)\ [1+m\cos(\Omega t+\psi)], \tag{8}$$

where m is the amplitude modulation factor.

If U_{m_1} is small then, after mixing with the "search" frequency voltage $u_2 = U_{m_2}\cos\omega_0 t$, the intermediate frequency will be:

$$u_3=U_{m_3}\sin\left[(\omega-\omega_0)t+\frac{\Delta\omega}{\Omega}\sin\Omega t+\alpha\right]\left[1+m\cos(\Omega t+\psi)\right]. \tag{9}$$

where $U_{m_2} = \rho U_{m_1} U_{m_3}$; ρ is a coefficient with the dimension of $1/v$.

Hence,

$$\frac{du_3}{dt}=-U_{m_3}\sin\left(\frac{\Delta\omega}{\Omega}\pi+\alpha\right)\Omega m\sin\psi, \tag{10}$$

i.e., the slope of the curve at point $t = \frac{\pi}{\Omega}$ depends on α and is proportional to the slope of the envelope. In this case the application of above method is difficult. However, in the overwhelming majority of cases large frequency values correspond to large voltage values (and vice versa), i.e., $\psi = 0$ or π. In such cases $\frac{du_3}{dt} = 0$, the characteristic stretch remains horizontal and the reading is taken, as if there were no stray amplitude modulation, without any additional systematic error.

It should, however, be noted that the highest point to which the "horizontal stretch" may rise for the first measurement is $U_m(1 + m)$ and for the second measurement $U_m(1-m)$.

If the stray amplitude modulation is very deep, the second measurement becomes difficult since with a small U_m the resolution of the method decreases. With a modulation when $m < 50\%$ and $\psi = 0$ or π, stray amplitude modulation affects but little the random error of measurement.

Measurement technique. According to the theory outlined above the block schematic of the measuring device should consist of a frequency-modulated generator, a "search" frequency oscillator, mixer, low-pass filter and an oscilloscope, whose horizontal plates receive the modulation frequency. In such a simple form the measuring device is suitable for measuring frequency deviations with a large modulation index ($\Delta f/F > 100$) for which the characteristic stretch degenerates into a narrow gap. Experience shows that f_{01} and f_{02} can be measured, when such gaps appear at the edges of the oscillogram, with an accuracy ensuring a frequency deviation error of the

order of 1-2%. If a lower measurement error is required, the image of the characteristic stretch must be enlarged. For this purpose it is necessary to use a scanning with a duration exceeding a little the duration of the stretch, which can be attained by using single-sweep operation synchronized with the modulating frequency.

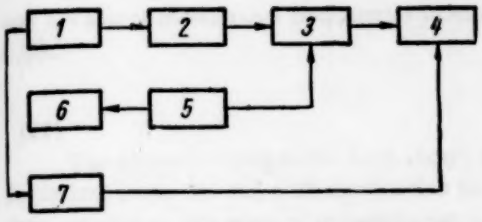


Fig. 3. 1) Low frequency; 2) generator of frequency-modulated oscillations; 3) mixer; 4) oscilloscope SI-1; 5) "search" frequency oscillator; 6) VVT-D wavemeter; 7) synchronizer.

Since the frequency of the "search" signal and the mean frequency of the frequency-modulated generator are not synchronized, α changes continuously which leads to a displacement, over the modulating frequency period of the characteristic stretch, vertically up and down. This displacement does not interfere with measurements, providing the modulating frequency is low, but leads to a complication of the oscillogram and greater measurement errors at high modulating frequencies.

Let us examine this phenomenon in detail. Let a characteristic oscillogram be observed at a modulating frequency of 25 cps and let the single sweep scanning be tripped by the same frequency. Since angle α varies, a smooth vertical displacement of the characteristic stretch is observed. If the modulation frequency is raised to 50 cps and the tripping of the sweep is also carried out at 50 cps, two separate vertically displacing characteristic stretches will be observed, owing to the persistence of vision. If τ_1 is taken as the time corresponding to the persistence of vision, the number of the characteristic pattern observed will equal τ_1/T. In order to observe at any modulating frequency, one characteristic stretch only, it is necessary to use time gating at 15-25 cps, either of the oscilloscope brightness or of its scanning, synchronized with the modulating frequency.

The block schematic of the measuring device is shown in Fig. 3. Oscilloscope 4 operates in a single-sweep condition, tripped by means of a synchronizer 7 with a frequency of 15-25 cps and negative pulses. The oscilloscope's vertical amplifier also serves as a low-pass filter.

For an accurate measurement of the "search" frequency a heterodyne wavemeter 6 is used. In order to be able to utilize the basic frequency of the interpolation generator, the carrier frequency of the frequency-modulated signal should be about 20 Mc. This frequency is obtained by heterodyning the initial frequency.

Any frequency divider can serve as a synchronizer, providing it can produce a frequency of 15-25 cps from modulating frequencies of 100 cps to 50 kc.

Errors of the method. The only systematic error of the method consists in possible distortions in the channel which transmits the signal $u=U_m\sin\left[(\omega-\omega_0)t+\frac{\Delta\omega}{\Omega}\sin\Omega t+\alpha\right]$. The type SI-1 oscilloscope's vertical amplifier has a straight-line amplification up to about 5 Mc which is amply sufficient in order to amplify above signal without any noticeable distortions up to frequency deviations of 2 Mc at modulation frequencies of 50 kc, since the effective band of such a signal is, according to Manaev's formula [4]

$$2F\left(1+\frac{\Delta f}{F}+\sqrt{\frac{\Delta f}{F}}\right)\simeq 5 \text{ Mc}$$

In order to evaluate the possible random error of the method let us examine its resolving power.

By differentiating $\frac{du}{dt}$ with respect to $\Delta\omega$ and taking a derivative at point $t=\frac{\pi}{\Omega}$ we obtain

$$\frac{d\left(\frac{du}{dt}\right)}{d(\Delta\omega)}=-U_m\cos\left(\frac{\Delta\omega}{\Omega}\pi+\alpha\right). \qquad (11)$$

At the optimum phase when the horizontal stretch lies on the X-axis we have $\frac{d\left(\frac{du}{dt}\right)}{d(\Delta\omega)} = -U_m$. After simple transformations and considering that the geometrical meaning of $\frac{du}{dt}$ is the tangent (tan β) of the angle of slope, which was horizontal when $\omega - \omega_0 = \Delta\omega$, we obtain that $d(\tan\beta) = U_m 2\pi F d(\Delta f/F)$.

Considering that $2\pi F$ corresponds to the length of the scan and U_m to half its height, and taking product $U_m 2\pi F$ to be of the order of 1 we obtain

$$\frac{\Delta f_1 - \Delta f_2}{\Delta f_1} \simeq \frac{d(\tan\beta)}{\frac{\Delta f}{F}}. \qquad (12)$$

If it is assumed that with a variation Δf it is possible to notice a 10° slant in the "horizontal" stretch, the relative random error of frequency-deviation measurements will according to (12) have the values given in the table attached.

It should be noted that a high precision in measurements with large modulation indexes given in the table can only be obtained with very stable mean modulation and "search" frequencies. Otherwise the characteristic stretch near the point $t = \pi/\Omega$ will rotate, due to the instability of these frequencies, about a mean horizontal position even when the deviation remains constant.

In effect it follows from (12) that

$$\frac{\delta f}{f} \simeq d(\operatorname{tg}\beta)\frac{F}{f}. \qquad (13)$$

where $\delta f/f$ is the relative variation of the mean modulation frequency due to its instability. In order to make the characteristic stretch deviate from the horizontal by no more than 10° during visual observation, it is necessary that

$$\frac{\delta f}{f} < 0{,}2\frac{F}{f}.$$

Obviously, the value of f cannot be made too small since it will then be difficult effectively to suppress after demodulation, signals with frequencies f and f_0, especially when large deviations are being measured.

In this connection the stability of frequencies f and f_0 for small values of F must be particularly good. For instance when F = 100 cps and f = 20 Mc, even if f_0 is considered to be perfectly stable, the stability of f must be of the order of $1 \cdot 10^{-6}$.

$\frac{\Delta f}{F}$	Relative error of measurement, %
10	2.0
50	0.4
100	0.2
500	0.04
1000	0.02

Measurement results. In order to determine the random error of the oscillographic method of measurement with respect to the modulation index $\Delta f/F$, ten measurements of the same deviation were made with different modulation indexes.

These measurements showed that the random error increases with a decreasing modulation index. However, when above equipment was used for measuring with large values of $\Delta f/F$ its error was larger than the calculated one owing to the instability of the frequencies f and f_0, and when measuring with small values of $\Delta f/F$ the measured error was smaller than the calculated one, since the characteristic stretch was very large thus providing a high resolution.

In order to ascertain experimentally the systematic error of the oscillographic method of measuring it was considered advisable to check the deviation measurements by means of a reference method.

The well-known method of measuring frequency deviation by means of "Bessel function zeros" was used as a reference. The error of this method does not exceed 1%.

The difference in the measurements made by means of these two methods of 25 deviations between 100 kc and 1.2 Mc at modulation frequencies from 800 cps to 50 kc and for various indexes of modulation did not exceed 1.3%.

CONCLUSIONS

The above investigations have shown that the proposed oscillographic method is suitable for measuring large deviations (over 100 kc) with modulation indexes exceeding 10 and carrier frequencies up to $7 \cdot 10^9$ cps; under these conditions the error of measurement is less than 1%. The equipment required for measurements by this method is simple and available in any radio laboratory.

LITERATURE CITED

[1] L. Hibbard and D. Caro, "Instantaneous measurement of a varying frequency", J. Sci. Instr. 29, 11 (1952).

[2] S. M. Rubchinskii, D. A. Vasil'ev, B. F. Kuz'min and N. I. Fedorenko, Radiotekhnika i Élektronika, No. 7, v. 1 (1956).

[3] A. M. Bonch-Bruevich, Application of Electron Tubes in Experimental Physics [in Russian] (GITTL, Moscow, 1955).

[4] E. I. Manaev, Radiotekhnika, No. 9-10,(1958).

RADIATION MEASUREMENTS

MINIATURE RADIATION METERS WITH ELECTRIC GENERATORS

B. Z. Votlokhin
Translated from Izmeritel'naya Tekhnika, No. 3, pp. 38-39, March, 1960

In handling radioactive materials it is necessary to have special indicating instruments which provide a rough indication of the presence of radioactive radiations and their intensity at the place of work.

For certain operations it is convenient to have indicating radiometers which can be placed in a side or breast pocket and made to provide a visual or sound registration of the discharge frequency of a miniature halogen counter.

The miniature radiometer RM-1 intended for detection of radioactive substances by their gamma or beta radiations with intensities up to 1000 μr/hr, despite its simplicity and convenience, has a substantial defect, namely the necessity of changing every month its 200 PMGTs-0.01-11 batteries. Often the lack of spare batteries prevents use of the instrument in everyday work.

Miniature radiometers not using batteries seem to have great possibilities. One of the methods for operating such instruments consists in using storage capacitors which are charged by means of manually or clock-spring operated generator. The generator charges capacitors of a sufficiently high capacity to feed the halogen counter and the high-impedance measuring circuit during a definite time (20-30 min). The author of this article made a portable radiometer fed by storage capacitors which are charged by means of an electric generator (Fig. 1).

The flashlight G generator was used in the set. In order to obtain the required high voltage of 210 v the stator winding of the generator was rewound with 0.03 mm wire with a total of 15,000 turns.

When button S is pressed contacts 1, 2 and 5, 6 are closed. The alternating voltage produced by the generator is rectified by germanium diodes D_1 and D_2 type DGTs-27. Diode D_1 operates as a half-wave rectifier. Capacitor C_3 is charged through diode D_1 to about 210 v. Diode D_2 serves to charge capacitor C_4 to double that voltage (420 v). Capacitors C_3 and C_4 are of the MBM type of 1 μf. These miniature capacitors work reliably at dc voltages up to 500-600 v (with a nominal breakdown voltage of 160 v), and have a very high insulation resistance of more than 10,000 meg (for a capacity of 1 μ f). A stabilizing unit is connected in parallel with generator G and consists of two neon indicator lamps T_2 type MN5 and a gas-filled stabilizer T_3 type SG5B.

Capacitors C_3 and C_4 are charged up to their working voltages by two-three even compressions of the geared driving handle of the generator. When the capacitors are charged, button S is released. This operation closes contacts 2,3 and 4,5. Capacitor C_3 is connected to the anode circuit of the cold-cathode thyratron T_1 type MTKh-90 and capacitor C_4 to the supply circuit of halogen counter type STS-1. Irradiation of the counter produces short discharges which result in current pulses flowing through resistance R_3 (10 meg) and the counter. The mean frequency of the discharges is determined by the intensity of the recorded radiations. The voltage pulses thus formed are fed through capacitor C_2 (type KTK of 33 $\mu\mu$f) to the control electrode of the cold-cathode thyratron T_1. Resistor R_1 (33 meg) serves to discharge capacitor C_2. When the triggering voltage appears on the control electrode capacitor C_1 (type KSO-5, 4700 $\mu\mu$f) discharges simultaneously through the thyratron and the winding of the output transformer Tr. Thus, every discharge of the counter is accompanied by a flash of the thyratron and a click in the telephone Te.

The telephone and the output transformer were taken from a "Kristall" hearing aid and are very small.

Capacitor C_1 is charged through resistor R_2 (47 meg) by capacitor C_3. The time constant $\tau = C_1R_2$ is made to equal 200 μsec, which is sufficient for registering the maximum measured discharge frequency.

Special attention in selecting the components of the circuit was paid to stability of operation, making the operating currents taken from capacitors C_3 and C_4 as small as possible and using miniature components.

The radiometer is mounted in a plexiglas box of 100 × 80 × 30 mm.

It has already been stated that the capacitors C_3 and C_4 have a very high insulation resistance. One charging of these capacitors will, therefore, provide with the chosen circuit capacitances and resistances the operation of the radiometer during 20 min.

The radiometer will register gamma and hard beta radiations. When registering hard beta radiations it is necessary to turn the grooves in the instrument body, which are placed above the counter and provide the penetration of the rays to it, towards the source of radiations.

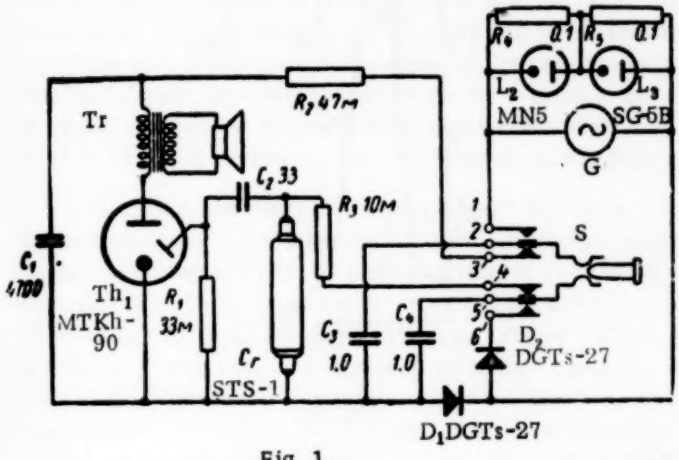


Fig. 1.

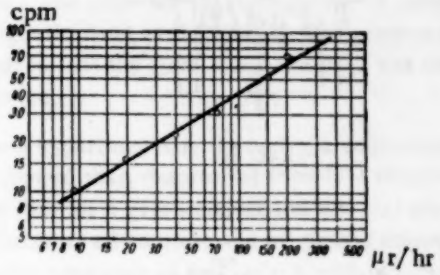


Fig. 2.

The intensity of the gamma-radiation dose can be determined approximately by measuring the number of discharges per unit of time by means of the thyratron flashes and clicks on the telephone. The relation of the number of pulses per minute and the intensity of gamma radiations is given in the calibration curve shown in Fig. 2.

The accuracy in determining the radiation dose amounts to about 25%.

If the MTKh-90 thyratron or the STS-1 counter are changed the meter should be recalibrated.

Normally in the absence of a radiation source the radiometer registers a natural background which produces single discharges (amounting on the average to some 10-15 per minute). The ear becomes easily accustomed to the rare signals of the natural background and an increase in their rate due to radioactive radiations becomes immediately noticeable.

The above radiometer has been checked extensively in operation and produced satisfactory results.

A MAGNETIC GAMMA-SPECTROMETER WITH AN "ANNULAR" FIELD

A. S. Karamyan* and P. T. Prokof'ev

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 39-41, March, 1960

At present there exist many types of gamma spectrometers. Depending on the energy region of the γ-rays under investigation, different interaction mechanisms between the γ-rays and the substance are used in the spectrometers (conversion and recoil electron spectrometers, etc). Some of the spectrometers described in literature attain very high resolutions [1-4]. In almost all these instruments, however, the solid angles of the knocked out electrons' capture are very small. In the majority of spectrometers with a high resolution "flat" magnetic fields

* Deceased.

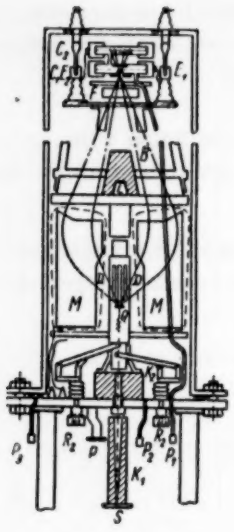


Fig. 1.

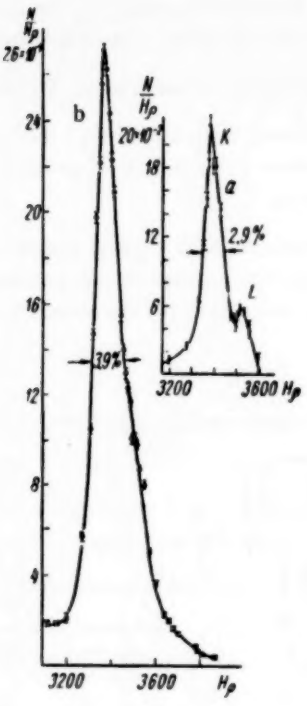


Fig. 2.

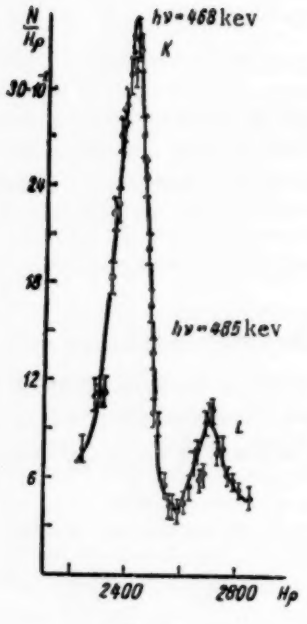


Fig. 3.

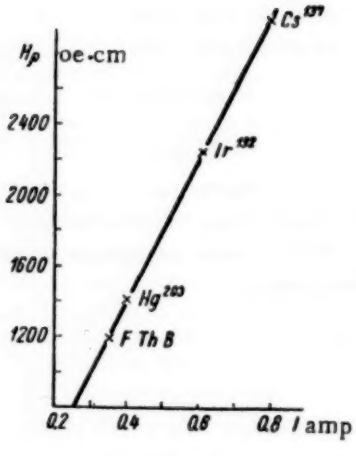


Fig. 4.

are used, i.e., fields whose configuration provides good focusing in a given plane of a wide monoenergetic electron beam (~30 to 40°). In these instruments, however, the angle of capture in the plane perpendicular to the main plane is, as a rule, very small (2 to 6°), thus providing a small over-all solid angle of capture ($\sim 10^{-3} \cdot 4\pi$). In this respect spectrometers with a volumetric, longitudinal field are a little better.

In spectrometers with a high luminosity a certain loss in resolution could be compensated for by possible evaluation of the relative intensity of lines in the γ-spectrum, including weak lines.

With this object in view we constructed a magnetic γ-spectrometer, intended for the investigation of γ-rays in the 200-700 kev energy range by means of photoelectrons. The instrument is designed for the best utilization of the characteristic angular distribution of the photoelectrons knocked out of the target by γ-quanta (Fig. 1).

The gamma-rays radiated from the source S, which can be placed according to the intensity of the preparation, either in a collimator or in direct contact with the target Q, knock out photoelectrons from the target.

The electrons, which leave the target at large angles to the direction of the γ-quanta, enter the magnetic field M in which they move along the arc of a circumference 20 cm in diameter, and on leaving the magnetic field along a tangent to that arc to a distance of 135.5 cm from the target they operate a registering system consisting of two Geiger-Mueller counters. In order to obtain a large solid angle of capture and taking into consideration the angular distribution of the photoelectrons, the magnet is made in the shape of a slotted cylindrical belt with a complex form of its input and output edges. The magnet consists of 20 wedge-shaped (the best shape) cores separated by plane-parallel gaps. Each core is wound with copper wire and all the windings are connected in series and fed through a special controlling device from a storage battery. It is obvious that in order to be able to focus the monoenergetic electron beam onto the input window of the first counter it is necessary in the first place to provide such focusing by each gap and in the second place that the foci of all the gaps should coincide. According to this requirement the shape of the core was selected first. The shape of the edges of the M cores (see Fig. 1) were obtained by calculation for a given slope of the magnetic field at the edges. Measurements of the distribution of the magnetic field showed, however, that although in fact the field in all the gaps was identical, it stretched beyond the core edges much further than was expected.

Therefore, the shape of the core edges* had to be finally chosen experimentally by taking a conversion spectrum of line $h\nu$ = 662 kev Cs^{137}. The experiment immediately showed that, despite the identical magnetic fields (within the accuracy of measurements) in the various gaps, the foci for a given conversion line did not coincide. The foci were made to coincide by a more accurate geometrical adjustment and by partial shunting of the magnetic fields in some of the gaps. Figure 2 shows a conversion spectrum of Cs^{137} taken with one open gap (curve a) and with all the gaps in operation (curve b). The widening of curve b as compared with a shows that all the 20 foci in the instrument have not been made to coincide completely. Since the electron path in this instrument is very long (~150 cm), the whole instrument is assembled, in order to decrease the effect of dispersion, in a copper tube which is evacuated to 10^{-2}-10^{-4} mm Hg. The determination of the trajectories which limit the angle of capture in the plane through the longitudinal axis of the instrument showed that in order to increase the luminosity of the instrument, it is necessary to enlarge the diameter of the magnet. In our instrument the diameter of the magnet is only limited by that of the copper vacuum tube which amounts to 350 mm. In this connection angle ϑ = 40°. In the plane perpendicular to the axis of the instrument, the angle of capture of each gap amounts to 5-6° and of the whole magnet to 100-120°.

Taking into account these data and the angular distribution of the photoelectrons it is possible to calculate the share of all the photoelectrons which can be focused by the instrument onto the registering device. For γ-quanta energies of 200 to 700 kev it amounts to 23%.

In order to decrease the effect of the background the registering was made by means of two Geiger-Mueller counters, connected in a coincidence circuit. The counters were filled with a mixture of helium and methane up to a pressure of 12 cm Hg (1.5 cm of methane and 10.5 cm of helium). The counter volumes were divided and the fields near the windows equalized by means of 1 μ thick nickel foil which was soldered to the window. Gold, lead and uranium foil, respectively, 10, 16 and 15 μ thick was used for targets.

After adjustments the instrument was calibrated with respect to energy, by means of the following lines whose energy is known: $h\nu$ = 662 kev Cs^{137}, $h\nu$ = 238 kev F-line ThB, and $h\nu$ = 279 kev Hg^{203}. As an example an Ir^{192} spectrum obtained on the instrument is shown in Fig. 3. A calibration curve of the relation of the current in the magnet to the energy of the γ-rays under investigation are given for a lead target in Fig. 4.

All these spectra were obtained for source intensities not exceeding ~200 μC. The ratio of the photopic luminosity areas obtained for given $h\nu$ values and different z targets (Au, Pb, U) were found to be (within the limits of measurement accuracy) in full agreement with the law of proportionality of the photoelectric effect yield to z^5.

Let us note that owing to the possibility of obtaining by means of this instrument from the same source under similar conditions both a conversion and a photoelectron spectrum, one can with appropriate calculations

*The required focusing of these gaps can be attained not only by selecting the shape of the edges, but also by an appropriate configuration of the field in the gaps.

or calibration use this instrument for measuring γ-ray conversion fractions in the 200 to 700 kev energy range.

In [5] some calculations and experiments in making a similar instrument with one and six gaps [6] are described. However, this instrument differs essentially from ours since its target and registering device are placed symmetrically with respect to the magnetic field, the field in the gaps decreases from the center towards the peripheries, etc. *

LITERATURE CITED

[1] N. Svartholm and K. Siegbahn, Ark. Mat. Astr. Fysik, 33, No. 21 (1947).

[2] A. Hedgran, Arkiv Fysik, 5, No. 1, (1952).

[3] B. S. Dzhelepov and A. A. Bashilov, Izvest. Akad. Nauk SSSR 14 (1950).

[4] A. V. Zolotavin Izvest. Akad. Nauk SSSR 18, (1954).

[5] O. Kofoed-Hansen, J. Lindhard and O. B. Nielsen, Mat.-Fys. Meddelelser, 25, 16, (1950).

[6] O. B. Nielsen and O. Kofoed-Hansen, Mat.-Fys. Meddelelser, 29, No. 6 (1955).

* The intended use of this instrument is different from ours, therefore the instruments are not completely comparable.

DISCHARGE COEFFICIENTS OF DOUBLE BEVEL DIAPHRAGMS

V. I. Romanenko

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 41-44, March, 1960

Normally the movement of viscous liquids along pipelines is represented by the smaller Reynolds numbers (Re). Therefore it is impossible to control Venturi tubes [1, 2] under conditions of a continuous production process, since the discharge coefficient for these constricting devices does not remain constant in the region of the smaller Reynolds numbers Re and is a function of the Re number.

One of the constricting devices in which the discharge coefficient remains constant down to very small Reynolds numbers, is a diaphragm with a double bevel (Fig. 1).

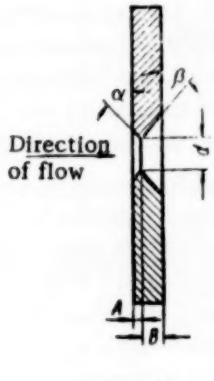


Fig. 1.

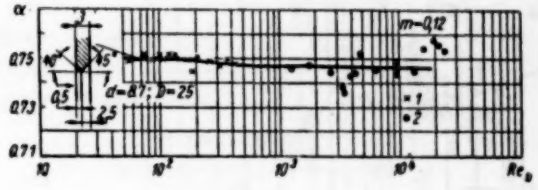


Fig. 2.

Fig. 3.

Experimental investigations of a double-bevel diaphragm discharge coefficient have already been carried out [3-6]. The relation of the discharge coefficient of a double-bevel diaphragm to the Re numbers according to [3] is given in Fig. 2, that according to [5] in Fig. 3 and that according to [6] in Fig. 4. Table 1 gives the dimensions of the double bevel diaphragms investigated by these authors.

In the Central Chemical Scientific Research Institute of Forestry we* experimented with the determination of the discharge coefficient of double-bevel diaphragms (Fig. 1). The diagram of the experimental equipment with heating of the operational containers and the pipeline through which the liquid (pine galipot) was flowing is shown in Fig. 5. The over-all height of the equipment is 12.6 m. Its maximum output 10 tons/hr.

The working liquid was heated up to the required temperature in container 1 of 1 m^3 and fed by the centrifugal pump 2 to the constant level tank 4. From tank 4 the liquid was directed by pipeline through diaphragm 7 to tank 10 of 0.26 m^3, placed on scales 11, or to funnel 20 -which directed it back to container 1. The overflow of small quantities of the liquid from tank 4 along pipe 5 was checked through sight hole 16. The water for heating the equipment was heated up in boiler 12 and delivered by centrifugal pump 14.

*N. S. Kuznetsova and V. A. Safonova participated in the experiments.

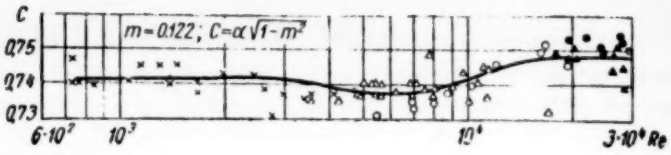


Fig. 4.

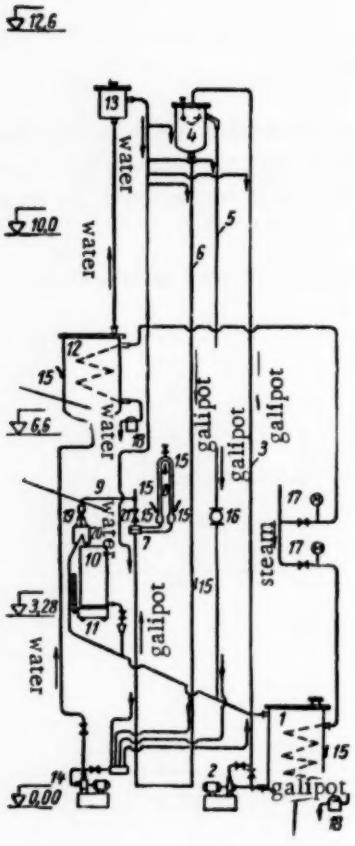


Fig. 5. 1) Container for heating the galipot; 2) pump for the working liquid; 3) pressure pipeline with heating; 4) constant-level tank; 5) overflow pipe with heating; 6) delivery pipeline with heating; 7) diaphragm; 8) diaphragm meter; 9) changeover pipe; 10) still water tank; 11) scales; 12) boiler for heating water; 13) supply water tank; 14) water pump; 15) thermometers; 16) sight hole for checking the overflow of liquid; 17) manometers; 18) condensers; 19) changeover device; 20) directing funnel; 21) discharge control valve.

The diaphragm (made of ÉL1T steel) was mounted on a vertical part of a tube with a diameter D = 50 mm between two ring chambers made according to the rules 27-54 [1].

The pressure difference in the diaphragm was measured by means of a U-shaped glass differential manometer, whose ends were connected to the ring chambers by 400 mm long pipes. Above the balancing liquid there was air in the differential manometer. The experiments were carried out at an ambient air temperature of 25°C. The temperature of the working liquid was measured with a mercury thermometer at a distance of 20D below the diaphragm. The temperature of the balancing liquid in the differential manometer was measured with a mercury thermometers built into the lower parts of the differential manometer branches. The brass scale of the differential manometer was calibrated with an accuracy of ± 0.1 mm. The height of the liquid columns in the differential manometer was observed visually rounding off the figure to the nearest ± 0.5 mm.

The amount of liquid which had passed through the diaphragm during the experiment was determined by weighing it on scales with a maximum of 500 kg and an error not exceeding ± 0.5 kg. In order to determine the density and viscosity of the liquid, 0.5 liter samples were taken after every 4-5 experiments. The density was determined with a pycnometer on analytical scales, and the viscosity with a viscosimeter VU according to the GOST 6258-52 method.

The working surface of the diaphragm was polished. The input edge of the diaphragm orifice was made so sharp that a ray of light incident to it was not reflected. The orifice diameter was measured on a measuring microscope UIM-21, and the bevel angles on measuring machine SIP. The experiment was timed with a stop watch.

The length l_s of the straight portion of the pipe in front of the diaphragm was equal to 30 D for a modulus of m = 0.3694 and 60D for the remaining moduli. In the first instance the pipe section was joined end-to-end to a straight pipe 68 mm in diameter and 2.5 m long and in the second case to a pipe 50 mm in diameter and 0.8 m long.

The straight portions of the pipe 10D in front of and 10D behind the diaphragm were bored out to a size of 50 ± 0.1 mm. The diameter of the remaining part of the straight section of the pipe in front of the diaphragm was enlarged to the same size by passing through it a tempered calibrated ball. The technique of determining the coefficient of discharge is described in greater detail in [7].

The dimensions of the diaphragms under test are given in Table 2.

TABLE 1

Authors	Pipe diameter D, mm	Diaphragm orifice diameter d, mm	Modulus $m=\frac{d^2}{D^2}$	$\frac{A}{d}$	$\frac{B}{d}$	α°	β°	Re	Range of Re number in which α = const	Liquid used in experiments
Witte /3/	50	–	0.12	0,06	–	50	45	200–4000*	α=0.745* for Re=600–4000*	Water and mineral oil
" "	25	8,7	0.12	0.057	0,287	50	45	60–10000*	α=0.750* for Re=60–300*	" "
" "	25	–	0.12	0,06	–	50	45	40–250*	α=0.747* for Re=300–10000*	" "
Ferroglio /4/	80	–	0.12	0,06	–	50	–	4000–70000*	α=0.744* for Re=100–250*	Water
Schmid and Schneider /5/	25	8,7	0.121	0.057	–	50	45	20–800	α=0.713* for Re=10000–35000*	Mineral oil
Schlag /6/	50	–	0.122	–	–	40	45	700–30000	α=0.750 forRe=150–800	Water
									α=0.746 forRe=700–3000	

Note: Data calculated by us from graphs in [3, 4] is marked with an asterisk.

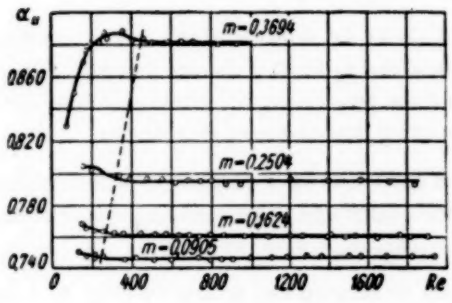


Fig. 6.

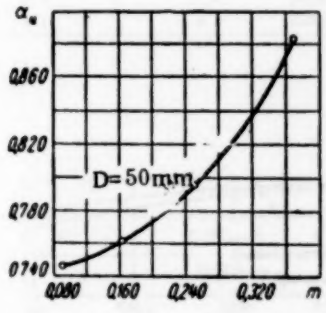


Fig. 7.

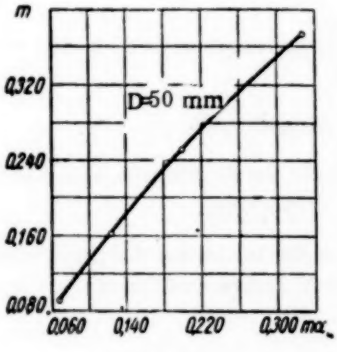


Fig. 8.

The empirical formula for calculating the discharge coefficient α_u has the form

$$\alpha_u = \frac{G}{3.479 \cdot 60 \tau d^2 k_t \sqrt{\gamma(\gamma_h - \gamma_1)H}},$$

where G is the weight of the liquid which has passed during testing through the diaphragm, kg-wt; τ is the duration of the experiment, min; d is the diaphragm orifice diameter at a temperature of 20°C, m; k_t is the correction factor for the heat expansion of the diaphragm; γ is the specific gravity of the working liquid, kg-wt/m³; γ_h is the specific gravity of the balancing liquid in the differential manometer, g-wt/cm³; H is the difference of levels of the differential manometer liquid, mm; and γ_1 is the specific gravity of air over the differential manometer liquid, g-wt/cm³.

Figure 6 shows the test results in the form of curves relating the initial discharge coefficient to Re numbers for various values of modulus m; each point on the graph corresponds to the mean value of the discharge coefficient obtained in three parallel experiments.

It will be seen from Fig. 6 that in the range of small Re values the curves have a maximum. To the right of the maximum points, the curves come down a little and then become parallel to the X-axis. The arithmetic

TABLE 2

d, mm	m	$\frac{A}{d}$	$\frac{B}{d}$	α	β	Initial discharge coefficient, α_u	Root mean square error $\sigma\alpha_u$, %	m_{α_u}	Range of Re numbers
15.05	0.0905	0.06	0.3	48°36′	44°49′	0.7465	0.08	0.0676	240—1930
20.15	0.1624	0.06	0.3	47°19′	45°16′	0.7615	0.10	0.1236	260—1900
25.02	0.2504	0.05	0.3	49°43′	45°48′	0.7953	0.15	0.1991	320—1830
30.39	0.3694	0.06	0.3	50°41′	45°30′	0.8824	0.18	0.3260	450—1000

TABLE 3

m	Re	Decrease in α_u, %	
		with the valve fully open	with the valve 50 % open
0.0905	1000	0	0
0.0905	1400	0	0.07
0.1624	1000	0	0
0.1624	1600	0.17	0.5
0.2504	1000	0	0
0.2504	1600	0.16	0.6
0.2504	2000	0.8	1.5

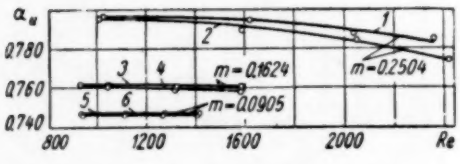


Fig. 9. In curves 1, 3 and 5 the valve is completely open; in curves 2, 4 and 6 it is 50% open.

mean of the discharge coefficients in the range of Re values for which the coefficients can be considered constant is taken as the initial coefficient α_u for a given modulus m. These values of α_u and those of the root-mean-square error $\sigma\alpha_u$ are given in Table 2.

The dotted line in Fig. 6 which represents the boundary values of Re, crosses the curves at points in which the discharge coefficient does not exceed 0.2% of the α_u values taken for the corresponding moduli.

Figure 7 shows the relation of the initial coefficient of discharge to modulus m for D = 50 mm and Fig. 8 the relation between m and the product $\alpha_u m$. These relations can be used for calculating double-bevel diaphragms.

Our tests show that for a diaphragm with modulus m = = 0.12 the initial discharge coefficient α_u = 0.7507 and for one with m = 0.121, α_u = 0.751 (Fig. 7).

According to Schmid and Schneider (Fig. 3) a diaphragm with a modulus m = 0.121 in the range of Re from 150 to 800 has a constant α_u equal to 0.750, i.e., in the range of Re = = 240-800 our data differ from those of Schmid and Schneider by 0.13%.

According to Witte's data a diaphragm with a modulus m = 0.12 in the range of Re 60 to 300 (Fig. 2) has a constant α_u equal to 0.750, thus differing from our data by 0.1%.

With 1900 > Re > 300 the discrepancy with Witte's data does not exceed 0.5%.

Figure 9 and Table 3 show the relation of the discharge coefficient to the Re numbers with a cork tap of a nominal diameter of 50 mm placed at a distance of 76D in front of the diaphragm.

It will be seen that as the Re number increases so does the effect of the tap on the discharge coefficient. this effect is more pronounced with a large diaphragm modulus and a small aperture of the tap.

CONCLUSIONS

1. The values of the initial coefficients of discharge for double-bevel diaphragms were determined for moduli of 0.0905, 0.1624, 0.2504 and 0.3694 in the Re range of 240 to 1900.

2. The root-mean-square error of the initial discharge coefficient did not exceed 0.18%.

3. The relation of $\alpha_u = f(m; Re)$ derived in the article makes the calculation of double-bevel diaphragms possible for Re values between 240 and 1900.

LITERATURE CITED

[1] Rules 27-54 on the use and checking of flowmeters with normal diaphragms, nozzles and Venturi tubes [in Russian] (Mashgiz, 1955).

[2] VDI- Durchfluß-Meßregeln DIN 1952, 6 Auflage, (1948).

[3] R. Witte, VDI-Zeitschrift, 87, No. 18/20 (1943).

[4] L. Ferroglio, L'Energia Elettrica, 19, 413 (1942).

[5] C. Schmid and K. Schneider, Erdöl and Kohle, No. 6 (1948).

[6] A. Schlag, Revue Universelle des Mines, No. 2 (1950).

[7] V. I. Romanenko, Hydrolysis and the Wood-Chemical Industry, No. 1, (1958).

ESSAYS AND REVIEWS

DIGITAL ELECTROMECHANICAL VOLTMETERS AND OHMMETERS

V. M. Shlyandin

Translated from Izmeritel'naya Tekhnika, No, 3, pp. 45-50, March, 1960

One of the most promising developments in modern electrical measurement techniques is the utilization of digital instruments which convert continuous variables into a discrete form.

The outstanding advantage of the digital instruments are their high precision and speed of operation, a clear and convenient display of recording and a very small power taken from the source of the measured signal.

Digital instruments provide complete automation of measurements and recording and, in combination with electronic computers, the automation of various production processes. The discrete form of registering is also the most accurate and interference-proof for remote transmission.

In this connection the digital instruments are becoming more and more widely used both in electrical measurements and in total automation of production. In several countries the mass production of such instruments for most diverse purposes has already been organized; for instance, in the USA over 20 companies are now producing digital voltmeters and ohmmeters (besides frequency meters, electricity meters, tachometers, clocks, ratio meters, pressure gauges, etc). Companies producing electrical instruments and nonlinear systems alone produce over 20 types of voltmeters and ohmmeters each. Many of these instruments are made up of standard units. The errors of these instruments vary between 2 and 0.01% (mostly 0.01%), the time for one registration (for electromechanical instruments) is between 3 to 0.3 sec (mostly 1 sec); the number of display digits varies between 3 and 6 (mostly 3-4 digits).

In the USSR attention was paid to the development of digital instruments a long time ago [1]. At present several organizations are conducting serious development work in making digital instrument models. Their mass production, however, by our instrument-making plants has not yet been organized.

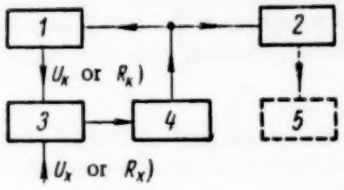
Basic types of digital instruments. These instruments can be divided into two groups, namely the electronic and electromechanical type instruments.

The peculiarity of the electronic instruments [2] consists in their high speed registration (up to tens of thousands of registrations per second). This property is of primary importance in special cases, for instance, in feeding information to electronic computers. In the electrical measurement technique this property is not decisive, since the reading and recording rates are limited. Electronic voltmeters and ohmmeters are relatively seldom used in electrical measurements, since their accuracy is theoretically limited (to 0.1-0.2%) and their cost is relatively high. Therefore we shall deal henceforth with electromechanical voltmeters and ohmmeters only.

The electromechanical digital instruments do not differ in the principle on which their measuring circuits are based from laboratory dc compensated instruments, since they use some form of automatic compensation. A simplified block schematic of a digital instrument of the electromechanical type is shown in Fig. 1. The measured voltage U_x (or R_x) is compared with the compensating voltage U_c (or R_c) in the comparing unit 3. If these voltages are unequal the comparing unit operates the control unit 4 which changes the condition of the compensating unit 1 until U_c becomes equal to U_x. Simultaneously the control unit changes the condition of the digital registration unit 2 and, if necessary, also, of the recording unit 5.

The compensation of the measured voltage by voltage U_c (balancing) can be either continuous or discrete.

Continuous balancing is attained as a rule by means of an electric motor which moves the slide of the compensation unit slide wire. The early digital instruments were based on this principle [3, 4 and 5]. Their accuracy, however, is limited by the use of the slide-wire and the dry-friction moment errors and cannot be made sufficiently high. The tendency to raise the accuracy of these instruments leads to a complication of their kinematics and makes them more expensive [6], which is not justifiable in practice. Mass production of such instruments, with the exception of certain individual cases, is not justifiable.



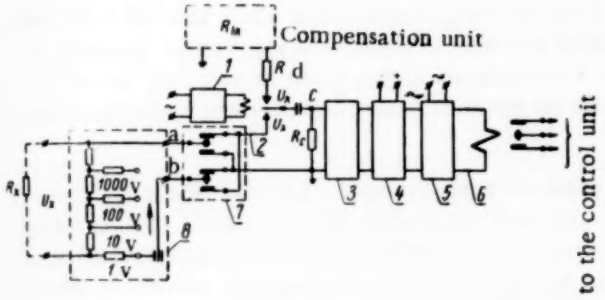


Fig. 2.

The control unit of discretely balanced instruments is constructed, as a rule, either from relay circuits [7] or step-by-step selectors [8, 9]. The compensation unit, similarly to modern laboratory compensators, is constructed from resistance boxes; hence the accuracy of these instruments is theoretically only limited by the accuracy of manufacture and stability of the resistors used, and can therefore be made sufficiently high. Thus, we shall now limit ourselves to describing electromechanical digital instruments with discrete balancing either static or dynamic.

In instruments with static balancing the control unit responds to the difference U_x-U_c and varies the condition of the compensating unit until these quantities are equal, and then it stops operating. In instruments with dynamic balancing the control unit periodically changes the condition of the compensating unit from its initial to its final state and the adjustment of the registering unit is completed and stops at the instant $U_x = U_c$. Each one of these methods has its advantages and disadvantages, but from the point of view of measurement technology they are approximately equally good.

The comparing unit actuates the control unit if the measured and the compensating variables are different and it must have a sufficiently high input impedance, sensitivity and stability; it must be sensitive to the polarity of the input signal so as to provide the correct direction of operation of the control unit, and finally it must withstand possible overloading at the input.

The principles involved in designing units which would satisfy the above requirements have long since been established. A typical schematic circuit of a dc voltmeter is shown in Fig. 2. It includes as its basic components a chopper 2 for converting dc into ac, a diode input signal limiter 3, and an ac amplifier 4 with a phase-sensitive final stage 5 and a polarized relay 6 at the output. The chopper is normally fed through an intermediate passive phase-shifting circuit 1 in order to synchronize the alternating voltage at the output of amplifier 4 with the alternating voltage fed to stage 5. In fully automatic digital dc voltmeters, a high resistance potential divider 8 is connected to the output and is supplied with an automatic range-switching device (operated from the control unit) and an automatic line-reversing device 7 in case U_x is wrongly connected (this operation is performed by a special relay in the control unit).

Digital ohmmeters use a bridge circuit which serves simultaneously for switching the range and for balancing and is placed inside the compensating unit [7, 10]. The unbalance voltage of the bridge circuit, is converted into a rectangular voltage and fed to the input of amplifier 4. The necessity to limit the input signal in this case is no longer required. The chopper connecting circuits at the input of the amplifier are numerous and are dealt with in detail in current literature which also deals with ac-amplifier and phase-sensitive circuits.

The compensating unit must produce discretely changing values of the compensating variable (U_c or R_c) which are compared over the entire measuring range with the quantity being tested. The discrete operation of the instrument is achieved, in the same manner as in normal laboratory compensators or bridges, by using a set

of resistors which are appropriately switched during balancing. All the normal requirements of the laboratory instruments must, therefore, be fulfilled, such as the stability of the operating current, which is set by means of an auxiliary standard cell, freedom from the effects of thermal emfs and contact resistances, stability and accuracy in the manufacture of the resistors, etc. The total error of the above factors must not exceed half the value of the last registered digit, since otherwise the last figure of the count becomes inaccurate.

For digital instruments additional requirements should be observed, namely that the compensating unit internal resistance R_{ic} should be constant or vary within such limits that the error of the instrument does not exceed half the last registered digit, the maximum number of connections (switching) for any possible registration in a given range should be made as small as possible, the required matching of the compensating unit with the control and registering units should be provided. The design of the compensating unit determines to a great extent that of the control and registering units.

Compensating circuits used in digital instruments are shown in Fig. 3. In Fig. 3a a normal compensator with a single (shunting) decade is shown with a variable position for the contact of the compensating voltage feed. Figure 3b shows a less popular compensator [11, 12, 13] which varies the working current I by switching the decade resistors and changing approximately the voltage drop U_c across resistor R_c. The point of tapping-off U_c can also be changed. Figure 3c represents compensator with a double decade and constant tapping-off point for U_c, and a constant total resistance in the working current I circuit attained by approximately switching similar section in the two decades. This compensator requires twice as many resistors as the compensator of Fig. 3a, but has a more constant sensitivity [14]. Figure 3d shows the circuit of the simplest bridge compensator which also has a constant tapping-off point for U_c. For digital voltmeters this is the most suitable circuit since it satisfies the majority of the requirements cited above [14]. Theoretically any of the circuits shown in Fig. 3 can be used both for static and dynamic balancing. In practice, however, it is best to use for static balancing circuits a and d, and for dynamic balancing b and c.

Static balancing. For static balancing only decimal resistance boxes are used. The registering device in this case can be linked directly (electrically or mechanically) with the position of the switches, thus providing a great advantage for this method. Electromagnetic step-by-step selectors are normally used as actuating devices, one for each decimal place. Other types of actuating devices lead to complicated kinematics, a lower reliability, and increased cost of the instrument, and cannot be considered suitable, a consideration confirmed by the existing practice in the design of digital instruments abroad.

The count of Fig. 3a circuits is increased by means of shunting decades [15].

The count of circuits of the type of Fig. 3d is also increased quite easily in practice [8, 9].

Dynamic balancing. For dynamically balanced instruments circuits of Fig. 3c are most commonly used in which the switching of resistors is most conveniently achieved by miniature relays. For decimal resistance boxes this method is not suitable since it requires too many relays, namely 10 for each decimal place. The number of required relays and, therefore, also, resistors can be greatly reduced if, instead of the decimal, the binary system is used. In such a connection the dynamic system becomes the only possible one, since in it a compulsory testing of all the positions (at least up to the moment of balancing) of the compensation circuit is required. Such compulsory cyclic (for each measurement or periodic) testing is normally carried out by a special addition step-by-step selector. In [16] information is supplied on the use for this purpose of magnetic switches without sliding contacts.

In the simplest binary compensator (Fig. 4) [17] the resistors in two boxes are chosen in the form of a series $R_i = 2^n R$, where n = 0, 1, 2, 3, . . . etc. The operating-current circuit always contains the full resistance of one box

$$R_0=(2^n-1)R.$$

Hence, the operating current is always constant and voltage U_c is proportional to the sum of the resistances connected in the lower box. If the number n of resistors in a box is 10 it is possible to obtain by means of the compensator any value of U_x between $U_x = RI$ and $U_x = 1023$ RI, i.e., it is possible to obtain a three-digital readout.

We shall examine the operation of the circuit which is shown, in the initial position, by an example of measuring $U_x = 125$ RI. In the initial position all the top contacts are closed and all the bottom ones open, i.e.,

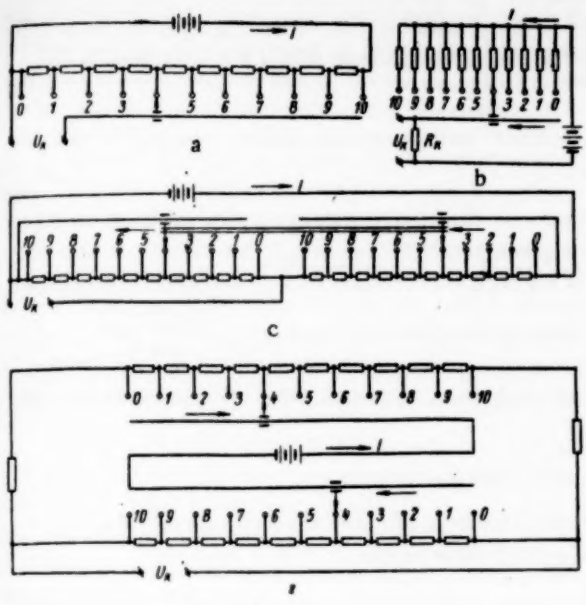


Fig. 3.

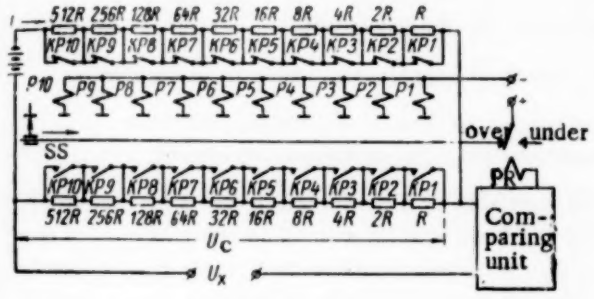


Fig. 4.

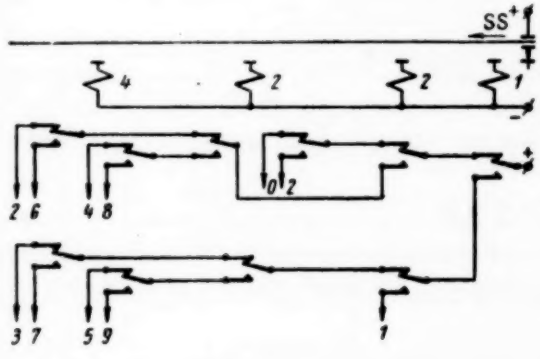


Fig. 5.

U_c = 1023 RI > U_x and the comparing unit switches the polarized relay PR contact into the left-hand side position (over) thus connecting the positive side of the feed to the wiper of the step-by-step selector SS.

When the selector is started, its wiper with the relay P_{10} makes contact and operates the relay which opens its top and closes its bottom contacts. Then we have

$$U_c=(1023-512)\,RI=523\,RI>U_x.$$

Contact PR remains in the "over" position and the selector wiper steps to the next contact. This connects relay P_9 while relay P_{10} locks itself by means of a circuit not shown on the drawing. This makes the compensating voltage equal

$$U_c=(523-256)\,RI=267\,RI>U_x.$$

Similarly after the next step of the selector it will be

$$U_c=(267-128)\,RI=139\,RI>U_x.$$

And after the next step

$$U_c=(139-64)\,RI=75\,RI<U_x.$$

The contact of relay PR is now thrown over to the "under" position and relay P_7 is disconnected leaving U_c = 139 RI. The next steps of the selector will proceed similarly to those described above

$$U_c=(139-32)\,RI=107\,RI<U_x;$$
$$U_c=(139-16)\,RI=123\,RI<U_x;$$
$$U_c=(139-8)\,RI=131\,RI>U_x;$$
$$U_c=(131-4)\,RI=127\,RI>U_x;$$
$$U_c=(127-2)\,RI=125\,RI=U_x.$$

Then the contact of relay PR remains in the neutral position and the measuring is over. The step-by-step selector can either stop (in acyclic balancing) or complete the remaining steps (cyclic balancing) but the measurement results will no longer be affected.

The disadvantage of the binary system of resistor connections is the complexity of the circuits for the subsequent conversion of the binary to the decimal system. This disadvantage is partially eliminated by using the tetradecimal system in which the resistance box is divided into sections with four resistors in each, and the corresponding resistors of each succeeding section are 10 times larger than those of the preceding section, i.e., each section corresponds to one decimal place. For the purpose of this system the series 1−2−4−8, 10−20−40−80 ..... could be used, in this instance, however,the sum of the numbers of each section is larger than 10 and it is more convenient to use a series like 1−2−2−4, 10−20−20−40 ..... or a series like 1−1−2−5, 10−10−20−50 ....., in which the sum of the digits in any section does not

exceed 9. With this arrangement the conversion to a decimal count becomes simple. Figure 5 shows as an example one of the possible circuits for converting a tetradecimal system into a decimal one. With any combinations of relay positions the output signal of the circuit will be transmitted to one of the appropriate devices for counting in the decimal system (from 0 to 9). The operation of the circuit, whose relays are all shown in the initial (nonoperated) condition, is clear from Fig. 5.

The principle underlying the construction of the tetradecimal compensation circuits is similar to the one shown in Fig. 4 and does not require any further explanation.

A disadvantage of the tetradecimal system as compared with the binary system consists in the increased number n of resistors (and, hence, relays) required to produce a given number N, although this number is smaller than for a decimal system. For a tetradecimal system $n = 4 \log N$, i.e., it equals 40% of the number required for the decimal system ($n = 10 \log N$) and about 20% higher than for the binary system $n = \frac{\log (N + 1)}{\log 2}$.

The main advantages of the relay instruments with dynamic balancing as compared with instruments using static balancing consists of:

the reduction in the total number of resistances in the compensating circuit;

the possibility of increasing the number of decimal places without a substantial complication of the compensating circuit or the control unit, by simply increasing the number of resistors;

a smaller maximum number of connections (switching) during measurements, i.e., a possibility of speedier operation.

Its main disadvantages are:

the practical impossibility of using the bridge circuit (of Fig. 3d) and therefore an undiminished effect on the measurements of the contact resistances and thermal emfs and a varying sensitivity;

the requirement of special circuits for the conversion of binary or tetradecimal systems into a decimal count, and therefore of relays with many contacts;

a different nominal value for every resistor of each resistance box of the compensating circuit.

Compensating units of digital ohmmeters. In measuring resistance it is convenient to use a bridge circuit with a resistance box connected in one of its arms. In this case the feeding voltage need be constant only to the extent of keeping the sensitivity constant, i.e., with a smaller degree of accuracy than that required for compensators. The tetradecimal connection of resistors in the variable arm of the bridge in conjunction with a relay system of dynamic balancing, controlled by a step-by-step selector, is the most suitable for a digital ohmmeter. This system, is, for instance, adopted in the Soviet-made automatic digital bridge.

Control units can differ considerably from each other. The circuits normally used are described in [7, 8, 9, 10, 12 and others] and are therefore omitted here.

Numerical readout unit. The main requirements of this unit consists in a clear and precise representation of figures, convenience of reading them and the determination of the required range. These requirements are best met by a readout system consisting of a row of large luminous numbers with ranges marked off by a luminous point in the right place [18, 19, 20].

It is often convenient to use for numerical display various mechanical and electromechanical devices of the type of numbered drum or tape counters with electromagnetic, motor or selector drives. In numerical-display instruments they are seldom used owing to the small size of their numbers, low speeds and complicated kinematics.

Another group consists of signal lamp and luminescent indicators. The signal lamps either consist of a network in which certain lamps light and form the outline of the required number when an appropriate code is received, or of seven straight lengths which form in certain combinations the required figures. In this case the decimal code must be first converted. In other versions ten signal lamps are placed behind a transparent plate with numbers marked on it thus forming one counting decade. The lighting of lamps illuminates the corresponding figures. In some cases the figures are engraved directly on the lamps.

In some of the digital instruments projection displays are used. In such a case each figure has its own lamp which projects the image of a diaphragm cut out in the shape of a figure onto a common frosted glass screen. Instead of a set of diaphragms in the shape of figures, seven straight line slots in various positions can be used. Then a definite combination of lamps will provide the image of the required figure on the screen (the decimal code must be first converted into the septenary).

Another method of numerical display consists in illuminating from one side (from the end) a transparent plate with the number engraved on it. All the plates are assembled in a packet one behind the other. Separate lamps are used for illuminating each plate.

Electroluminescent numbering is the latest achievement of foreign technique. These indicators consist of glass plates coated on their reverse side with a transparent conducting layer (the front electrode) which is covered with a phosphorescent dielectric layer (glowing layer). The back electrodes are made of separate metal segments. The segments are fed from the coding device with voltages of the order of 150 v at 10 kc. Various segment combinations provide the required figures from 0 to 9 when a voltage is impressed on them.

The third group consists of electron-beam number indicators, which include gas-discharge lamps, decade counters, and cathode-ray tubes. Glow gas-discharge tubes with a common anode and 10 separate cathodes are the most suitable for numerical-display instruments. Such indicators have the size of normal tubes, they are inexpensive, provide a good image of the figures and do not require the conversion of the decimal code into any other code. The Nixi type indicators consist of a set of 10 tubes of the shape of numbers illuminated by the glow discharge. In other indicators the cathodes are made in the shape of numbers which light if a voltage is applied between them and the anode, or bright spots are formed behind numbers engraved on the glass surface of the indicator, etc.

In addition to the numerical display these instruments can also provide data suitable for recording. Both foreign and Soviet plants make for this purpose special printing attachments.

CONCLUSIONS

The electrical numerical-readout measuring instruments have many important qualities and should in the near future acquire a correspondingly important place in our measurement technology. Electromechanical instruments with discrete static balancing (in a bridge compensator circuit) for voltmeters and dynamic balancing for ohmmeters with a gas-filled tube indicator display for each decimal place seem to be the most suitable types.

LITERATURE CITED

[1] F. E. Temnikov, Author's certificate No. 49959 of July 10, 1935.

[2] V. V. Kovalevskaya, O. N. Nolandt and V. N. Khlistunov, Priborostroenie, No. 11, (1958).

[3] R. F. K. Herzog, Rev. Sci. Instr. 1954, 25, No. 12.

[4] A. Nuut and C. Munsey, Electronics, 1956, 29, No. 1.

[5] R. F. Scott, Radio-Electronics, 1956, 27, No. 4.

[6] M. P. Tsapenko, Priborostroenie, No. 1, 1957.

[7] G. M. Zhdanov, Telemetering [in Russian] (v. 2 Gosénergoizdat, 1953).

[8] V. M. Shlyandin, Izmeritel'naya Tekhnika, No. 4, (1956).

[9] V. M. Shlyandin, Izmeritel'naya Tekhnika, No. 2, (1957).

[10] D. I. Malov, Bulletin of the Higher Educational Establishments, "Electromechanical" series, No. 7, 1958.

[11] K. A. Netrebenko, Izmeritel'naya Tekhnika, No. 4, (1958).

[12] G. V. Der-Shvarts and K. A. Netrebenko, Priborostroenie, No. 9, (1958).

[13] A. F. Kay, Communication and Electronics, No. 36, (1958).

[14] K. B. Karandeev, Electrical Measuring Methods [in Russian] (Gosénergoizdat, 1952).

[15] H. H. Emschermann, Archiv für Technische Mässen, No. 246 (1956).

[16] S. Meyer and M. Blynn, Instruments and Automation, 30, No. 12, (1957).

[17] S. K. Dean and D. F. Nettel, Electronic Engineering, 28, No. 336 (1956).

[18] E. Sack, Communication and Electronics, No. 35 (1958).

[19] Numerical Readout, Instruments and Automation, 1958, v. 31, No. 6.

[20] G. Schneider, Elektronik, No. 9 (1958).

MATERIAL RECEIVED BY THE EDITORIAL BOARD

PROBLEMS OF ORGANIZATIONAL AND TECHNICAL PREPARATIONS OF TEMPORARY BRANCHES IN RURAL AREAS

V. V. Petropavlovskii
Translated from Izmeritel'naya Tekhnika, No. 3, pp. 50-52, March, 1960

Functional provisional branches are the basic means of inspection in rural areas adopted a long time ago by the State Service of Measures and Measuring Instruments and preserved for further use by the Committee's rule 12-58 introduced on January 1, 1960.

The 4000 rural districts of our country use a large proportion of the measuring equipment employed in our national economy, including all the measures and measuring instruments used in agriculture, whose employment of various measuring devices constantly rises. A timely and exhaustive check of all the measures and measuring instruments in rural districts is an important task, since it ensures an efficient and accurate accounting and measurements of the agricultural and industrial production carried out in rural areas.

The local agencies of the Committee, the State Inspection Laboratories and the Interdistrict Repair Departments organize each year over 3000 provisional branches in rural areas and have thus accumulated a considerable experience in this work. However, the work of many provisional branches cannot be considered satisfactory, since a large number of measures and measuring instruments remain unchecked in the rural areas, particularly in agriculture and especially in collective farms, which of course is harmful to our national economy. It is, therefore, very important greatly to improve the technical organization of the provisional branches in the rural areas.

The unsatisfactory organizational and technical level of work in the branches consists in the lack of the required preparations for their display of initiative, in completely insufficient supervisions of their work, and in a low level of accountancy in the provisional branches.

The bad planning of the work of provisional branches becomes immediately apparent in the lack of instructions to the head of the branch when he leaves for the locality, i.e., he has no initial data for making a plan and schedule of inspection work in his provisional branch without which he cannot even determine accurately the duration of this work. Many State Inspection Laboratories specify the same duration of work for all their branches without due consideration of each case. Thus, the allocated time is too long for some of the branches and leads to unnecessary expenditure of time and money, and for other branches it is too short, the work is skipped and as the result of it a considerable amount of equipment remains uncertified by state inspectors.

The weak organizational work lacking in initiative of the heads of the provisional branches is due to the appointment to the jobs of insufficiently qualified people, and also by the lack of supervision of their work, or by insufficient and superficial supervision. Often the supervision amounts to checking the quality of the inspected instruments, a sample inspection of two or three places and assessment of the amount of work done without checking it against the equipment inventory, which often is not even compiled. The work of the provisional branches is also hindered by the practice which exists in many State Inspection Laboratories of recalling the head of the provisional branch as soon as the District Soviet Executive Committee passes its resolution on the beginning of the State inspection. The provisional branches then run of their own accord and any technical or organizational supervision of their work is completely out of the question, thus predetermining unsatisfactory results of the work. Unsatisfactory results are also often due to the supervision by one inspector of two provisional branches running simultaneously in different districts. Often local authorities pay little attention to the compiling of quality reports by the provisional branches and analyzing the material contained therein, which should serve as the basis for planning inspection and checking work in the future.

The work of the provisional branches is also badly affected by the unsatisfactory work of the instrument repair organizations (traveling weighing-equipment repair crews) and the lack of discipline on the part of the owners of the equipment who try to avoid state inspection of their equipment. A thorough organizational and technical preparation of the work of the provisional branches and active supervision of the work itself should eliminate completely these defects.

What should the organizational and technical preparations for the setting up of provisional branches in rural districts consist of ?

1. When the plans for the following year's provisional branches are being worked out it is necessary to devote some thought and consideration to compiling a list of districts in which the setting-up of provisional branches is planned, to analyze with due attention the reports of the provisional branches for the preceding period in order to obtain an idea of the amount of inspection work in hand. It is not necessary to set-up every year provisional branches in all the rural districts of the region, area or republic. Such a method of yearly servicing, especially in regions with many districts, does not permit one to pay sufficient attention to each provisional branch, since the State Inspection Laboratories are then more interested in fulfilling the plan for all the provisional branches and cannot pay due attention to the quality of their work.

It is also incorrect to conduct yearly inspections in exactly 50% of the districts irrespective of the condition of their measuring equipment. In compiling the list of the rural districts due for inspection it is necessary to base one's considerations on the economic advisability of the inspection, the number of instruments to be inspected and repaired, and the capacity and condition of the instrument repair shops, etc.

The distribution of the inspection in rural districts according to the seasons of the year is of great importance. Transport and climatic conditions, periods of agricultural work, etc.should all be taken into consideration.

2. The allocation of rural districts to inspectors must be real and not nominal, so that each inspector could have the possibility of studying systematically the reports from his own districts and know the inventory and condition of the measuring equipment and the organization of supervision over it in each of his areas and plants.

3. All the data about the amount and composition of the forthcoming inspection work is based on careful consideration and detailed analysis of the reports from a given district for the preceding period should be prepared for each provisional branch.

It is necessary to provide information on the items to be inspected (both with respect to type and location) for each place in the district, and especially for the district administrative center; and an inventory of all the measures and measuring instruments,with totals for various types and departments.

A preliminary estimate should be made of the instruments which are to be delivered for checking to the provisional branch, the Interdistrict Repair Department or the State Inspection Laboratory and those which can be checked on the spot, and of the sum of expected levies. Such an item as truck weighbridges should be taken into account since their number is rapidly rising in collective and state farms; the volume of checking and especially repair work in the localities is often determined by this item alone.

The above data will provide an estimate of the duration of the provisional branch work if one takes into account the time of the year, transport facilities, the size of the instrument-repair organizations, the number and location of the state inspection and repair points, etc. Moreover, this information will help to determine whether a mobile laboratory is required, establish what checking it can carry out in a given time and,hence,what testing and standard instruments should be supplied to the laboratory. It is possible to estimate the itinerary and the mileage to be covered by the mobile laboratory in the district.

This data will also help to find the approximate requirements in the repair of instruments both with respect to their quantity and types thus making it possible to organize an instrument-repair flying crew and supply it with the required equipment. Such a crew will require trucks for rapid transportation of weighing-equipment mechanics to the repair points and locations of the weighbridges. For the convenience of customers the weighing-equipment repair shop should have a stock of spare scales and weights which can be exchanged for the defective ones.

4. At the same time, data should be prepared for general inspections, checking by the GSMP, supervision of the work of the departmental inspection agencies, etc. Items subject to inspection by these various agencies should be listed according to departments and localities. Moreover, in planning this inspection work checking of those items which had not previously been inspected should be provided.

In compiling a general inspection plant it is necessary to acquaint oneself carefully with the types of instruments to be inspected in order to be able to prepare the required testing and standard instruments.

5. In compiling a plan of the inspection work it is necessary to take into account similar work carried out before the provisional branches were installed, so as to include in the plan only items actually requiring inspection.

Having received the task-plan of inspection work for a given district, which has been approved by the chief of the State Inspection Laboratory, the head of the provisional branch must study carefully all the items of the plan and compile his own plan and schedule of work for the provisional branch. At the same time the draft resolution of the Soviet District Executive Committee on the state inspection of instruments in the district should be prepared and should, specify inspection dates for various village soviets and dates for setting up checking and repair points in specified villages and farms of the district.

The chief of the State Inspection Laboratory is responsible for and should carefully check that the head of the provisional branch is well prepared for his job, understands clearly his task, is supplied with the required data for his inspection and repair work, that all the necessary testing and standard instruments are available, and all the required specifications are supplied.

The above article does not, of course, exhaust all the organizational and technical work involved in setting up a provisional branch, work which should be carried out by the state laboratories taking into consideration the local condition.

Editorial Note: Taking into consideration the importance of the checking and inspection work in rural districts and the necessity of improving it in every way, the editorial board has published V. V. Petropavlovskii's article in this issue.

Although the author notes that the Committee's regulations 12-58, which came into force on January 1, 1960 retain the provisional branch as one of the basic methods of inspection work in rural districts, his article does not stress sufficiently that one of the principle provisions of above regulations is the assignment of responsible state inspectors to definite districts.

This new measure will eliminate the lack of responsibility and the servicing of the measuring equipment in rural districts, will improve this service, and undoubtedly bring essential differences to the organizational work in setting up provisional branches, since the inspector whose is assigned to a district will always keep in touch with that district and in certain cases, when the district is large or far-removed, will reside there permanently.

With the coming into force of regulations 12-58 the organizational role of the State Inspection Laboratories and individual state inspectors is greatly enhanced.

With the introduction of regulations 12-58 the local agencies of the Committee will accumulate experience of great practical value for inspection work in rural areas under the new conditions. The editorial board requests the workers in the State Inspection Laboratories, especially state inspectors assigned to rural areas to share their experience with our readers on the pages of this journal.

INCREASING LABOR PRODUCTIVITY IN INSPECTION WORK

E. S. Adaryukov

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 52-54, March, 1960

In the light of the decisions of the Plenum of the CPSU Central Committee, raising labor productivity in inspection work is acquiring special significance.

The working experience gained by the electrical group of the Rostov State Inspection Laboratory of Measuring Equipment is significant.

At the beginning of 1958 this group consisting of 6 people failed to deal with its inspection work, the instruments belonging to various establishments were held up in the laboratory for long periods of time and the head of the group insisted on an increase in the personnel.

Yet owing to the lack of factory test benches, much time was spent unproductively on preparatory operations, such as the selection of the required instruments and leads, discussions about and the assembly of the testing hookup. This was especially pronounced in testing current transformers, galvanometers and other instruments for which 50% of the testing time was spent on preparatory operations.

Moreover the assembled hookups did not always conform to the technical requirements specified in the regulations, thus lowering the accuracy of testing.

The testing of many electrical measuring instruments by means of hookup inevitably led to narrow specialization, and thus lowered the efficiency of the group as a whole.

In order to raise labor productivity it was decided at the beginning of 1958 to transfer all the testing to permanent installations, and to assemble all the equipment required for the purpose exclusively by the means and personnel available at the laboratory; this equipment included: sets for measuring current and voltage transformers by means of the AIT instrument; sets for checking galvanometers of all types (the set includes a single and double bridge which also provides the testing of bridges and resistance boxes); comparators for checking ac ammeters and dc and ac voltmeters; sets for checking potentiometers and standard cells, for checking grade 0.5 milliammeters with a continuous current adjustment for scales of 1 ma to 1 amp, for testing resistors in a chamber equipped with a heater and a refrigerator type FAK-0.7 of the Kiev State Inspection Laboratory; a type of potentiometer set for checking grade 0.2 and 0.5 ammeters and voltmeters by means of a transistorized potentiometer type R 2/1.

The productivity of labor due to the use of above sets increased to such an extent that the personnel of the group could be reduced by one man; another man could be employed 50% of his time as the head of a mobile test laboratory (PPL) and the number of the electrical instruments checked by the group could be raised to 4000.

Each worker in the group became acquainted, on the average, with three to four new test techniques, thus increasing the general labor productivity.

The transfer of testing to permanent installations has also improved considerably the appearance of the laboratory, raised the operational skill and proved very useful in training workers of the factory laboratories.

In order to raise the labor productivity the Rostov State Inspection Laboratory has rationalized certain labor-consuming tests in its thermotechnical department.

The efficient work of permanent departments and mobile test laboratories is also of great importance.

The lack of premises for the Sal'sk, Taganrog and Shakhty interdistrict branches prevented the testing of electrical thermotechnical, linear and angle-measuring instruments in those districts.

Owing to inadequate preparation of the journeys of traveling crews and the lack of three-phase supplies, the work of the mobile test laboratories was also badly organized.

In 1958-59 a new building for the Sal'sk interdistrict branch was constructed and premises which satisfy our requirements found through the intervention of local Soviets in Taganrog and Shakhty. The permanent branches of the laboratory were equipped with stationary UPS-1 sets, horizontal and vertical telescope calipers, test plates, sets and devices for linear and angle measurements, sets of presses for checking manometers, thermostats and other test equipment, thus extending the types of instruments which it was now possible to measure in the permanent branches.

At the same time the other important problem of the efficient work of the mobile test laboratories was also being solved.

Taking into account the great saturation of the Rostov region with measures and measuring instruments, and the lack of reserves in the hands of customers of certain types of instruments, (especially of electrical and pressure-measuring instruments), we organized two types of mobile test laboratories.

The first type laboratories were mounted on GAZ-69 trucks, and put under control of heads of the provisional branches; they were supplied with sets of standard weights of 20 kg each in wooden containers, inspectors' three-

arm scales with a set of appropriate weights, a set of tapered measures of 2, 1 and 0.5 liters in a box, a comparator meter, etc.

The mobile test laboratories of the second type were installed on GAZ-51 truck chassis within a metallic body of the PAZ-653 type, which are light and easy to handle owing to their low mounting. The trucks are supplied with a three-phase installation type PTU-1 and a set of standard instruments and, a press with a set of manometers. The PTU-1 equipment was installed in the truck after it had been partially altered in the laboratory in order to make it more transportable, thus making it work for 12-18 months without any repairs.

The most qualified senior technical inspector who had a driving license was put in charge of the laboratory.

The mobile test laboratories' journeys are preceded by considerable preparatory work of the man in charge of the laboratory, in conjunction with various regional organizations, when their outlying branches have to be serviced, or in conjunction with the heads of the provisional branches, when it is required to service organizations and plants located in the area of the district. Such an arrangement makes it possible to plan the servicing of the establishments, inspecting one of them while the other is preparing its instruments for inspection.

The above organization of work made it possible to check a large number of instruments in many establishments, raised the laboratory productivity and the effective use of the testing equipment, helped to save state funds, and did not deprive the establishments of instruments in short supply for any length of time.

The advisability of group servicing of establishments is proved by the numerous favorable references made by the heads of these establishments.

Mobile test laboratories are being successfully used in servicing individual establishments.

Each State Inspection Laboratory is now accumulating valuable experience in rationalizing inspection work. The republic administrations of the Committee's representatives should systematically draw general conclusions from this experience and make it available to others.

REVIVING THE ACTIVITY OF INDUSTRIAL LABORATORIES

N. G. Klyuchnikov
Translated from Izmeritel'naya Tekhnika, No. 3, pp. 54-55, March, 1960

K. N. Katsman* is correct in his estimate of the organization and activities of industrial test laboratories. Many comrades support his opinion on enlarging the functions of the Central Test Laboratories. Experience has shown that inspection work requires smaller efforts, knowledge and persistence than introducing into production new measuring methods.

The one-sided orientation of the activity of the Committee's local agencies directed exclusively to the maintenance of the uniformity of measurements, hinders the development of the initiative of the industrial test laboratories, is passive and leads to a lag behind the requirements with which the measurement techniques are faced by the modern production conditions.

The subordination of the industrial test laboratories to the Technical Control Divisions limits their activity and reduces it to purely inspection functions. Subordination to the Technical Control Divisions lowers the role of the Industrial Test Laboratories. Hence, the suggestion to subordinate the laboratories to the Chief Engineer is correct. If there is no scrap in production due to measuring instruments, the Control Division and labor departments tend to decrease the laboratory personnel, raise without justification the scheduled intervals between inspections of the measuring equipment and reduce the number of laboratory and control and measuring instrument inspectors.

*See Measurement Techniques No. 4, 1959.

In view of the limited functions of the laboratory and measuring instrument inspectors, their pay is fixed at the level of auxiliary shops. For this reason technicians and engineers do not like working in the Industrial Test Laboratories and Control and Measuring Instrument shops, even immediately after completing their studies.

The training of factory metrologists takes a long time; they must be thoroughly acquainted with the measuring instruments and be able to solve various metrological problems. Frequent staff changes especially in this department are inadmissible.

The functions of the industrial laboratories should be widened and at the same time they should be supplied with qualified personnel whose pay should be based on that of workers in the main shops.

In his article K. N. Katsman raises the question of the relative importance of modern methods of quantitative evaluation of physical properties in production(introducing modern measuring methods) and the maintenance of the uniformity of measurements. Such a comparison is incorrect. Inspection work is inseparable from the introduction of modern means and methods of measurement.

We check by means of instruments (precision theodolites and leveling instruments) special equipment, bridge cranes and lathe equipment, and help as far as possible in the repairs of this equipment.

Occasional checking of these special metal-working lathes, showed large deviations from the set geometrical parameters. It is necessary to check the lathes by means of instruments and render assistance to the repair crews. Yet owing to bad organization these problems remain unsolved.

Metrological assistance is also required by the crews assembling new lathes or machines, assistance which, according to the experience gained, speeds up assembly and raises the quality of the lathes and reduces the amount of handling.

Making of details with great accuracy is often required in the shops. Metrological problems involved in making these details can only be solved by the Central Test Laboratory of the plant.

The laboratory personnel strived to establish a gear-measuring laboratory, in order to raise the quality of the gear-measuring instruments, but this could not be done owing to the reduction of the laboratory staff.

For the reasons given above interchangeability is at a low level; thus parts of large units supplied by various plants often do not fit, the measuring equipment designed by the chief technologist's department is often imperfect or unsuitable, the introduction of automation is hindered by the limitation of the functions of the Central Test Laboratories.

K. N. Katsman raised the question of the "blank spots" in the work of the departmental inspection agencies; there are many of them and they cannot be overlooked by the workers of the industrial laboratories.

The author of the article proposed to unify the test laboratories in plants. It is impossible to solve such problems immediately, especially in operating plants, where great difficulties may arise with respect to premises and their reequipment.

The unification of the laboratories of a plant will also presumably involve the establishment of a single repair shop for precision instruments where all the measuring instruments of the plant can be repaired; at present this work is done mostly by handicraft methods.

It is necessary to discuss these questions at industrial conferences with the participation of the chief engineers, heads of the Central Test Laboratories, chief metallurgists, power engineers and State Inspection Laboratory representatives, in order to work out a plan in agreement with modern production requirements.

The time is also ripe for the organization of an institute of industrial measurement techniques attached to the Committee of Standards, Measures and Measuring Instruments based on the "Kalibr" and BV plants with the following functions: designing models of measuring equipments, their testing and introduction into industry, and the coordination and planning of research and experimentation which is being conducted at the plants; this institute must be responsible for the development of the measurement techniques in the plants of our country.

THE NECESSITY OF PRODUCING A REFERENCE BOOK FOR THE REPAIR AND ADJUSTMENT OF MEASURING INSTRUMENTS

A. N. Andrianov

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 55-56, March, 1960

An increasing saturation of our national economy with measuring equipment requires a simultaneous development of measuring-equipment repair organizations. The development of the instrument-repair industry cannot be achieved as long as there is a lack in technical literature dealing with the description, repairs and adjustment of the widely used measuring instruments and tools. Neither has the exchange of experiences of the leading instruments-repair establishments been organized on a wide scale. As the result of this defect the control and instrument shops in plants, repair establishments and shops often experience great difficulties in the repair of measuring instruments, especially of new ones, and sometimes even refuse to repair some of the instruments.

The problem of issuing literature for the servicemen is not new.* The necessity of issuing books and pamphlets on the repair and adjustment of measuring instruments is obvious.

The most radical solution of this question would be the issuing of a large reference book on the foundations of repair and adjustment of measuring instruments, in which side by side with informative material on the existing measuring equipment there would also be a popular exposition of the theoretical information necessary for the principal readers of such a book, the workers in the control and measuring-instrument shops and instrument-repair establishments, in order to raise their qualifications. Too brief and garbled a reference book would not be useful enough and would not satisfy the requirements of the servicemen and adjusters. The book should be amply illustrated by drawings, sketches and diagrams intelligible to ordinary servicemen.

The widest possible circle of specialists competent in this sphere should engage in compiling the book. In preparing the reference book it will be necessary to find, by means of an exchange of experiences, the best practical method of repairing and adjusting measuring instruments. This material should be supplied by the instrument-making and instrument-repairing establishments and highly qualified servicemen and adjusters, who have a wide experience in this field.

The layout of the proposed reference book, divided into types of measurements, can be roughly as follows:

1) repair and adjustment of universal measuring equipment;

2) repair and calibration of machines and instruments for testing the mechanical properties of materials;

3) repair and adjustment of tachometers;

4) repair of reduction valves, manometers, and vacuum meters;

5) repair and adjustment of analytical and reference balances of the I, II and III categories;

6) glass measures of capacity and their calibration;

7) repair of flowmeters, steam gauges, water meters and other instruments measuring the flow of liquids and gases;

8) repair and adjustment of opticomechanical instruments;**

9) repair of single-phase and three-phase electricity meters;

10) repair and adjustment of electrical measuring instruments, etc.

Each section should contain at least the following information:

the principle of operation and the construction of the instruments, their kinematic, electrical and other diagrams;

---

*See for instance "Measurement Techniques," No. 1, 1958.

**In 1958 the "Mashgiz" press issued a relatively complete book by A. V. Érvais which corresponds to A. N. Adrianov's requirements in that sphere. The book was reviewed in "Measurement Techniques," No. 6, 1959. – Editors' note.

basic faults and practical methods of eliminating them;

special devices and instruments, as well as reference instruments required for the repair and adjustment of the measures and measuring instruments of a given type;

auxiliary materials and equipment.

The problem of compiling and issuing such a reference book must be solved in the near future. Not only the workers in instrument-repair establishments, but also those in departmental and state inspection agencies are interested in the production of this book.

THE PROBLEM OF MEASURING EQUIPMENT REPAIRS HAS BEEN OVERLOOKED

V. N. Shchukin

Translated from Izmeritel'naya Tekhnika, No. 3, p. 56, March, 1960

Why is the problem of literature for the repairs and adjustment of measuring instruments so topical? The scientific and technical press issues hundreds of book titles, yet there are hardly any books dealing with this question, and other books only gloss over the repair and adjustment of measuring instruments.

In 1948 the Mashgiz press issued A. I. Rozin's book entitled "Gaugermechanics." Despite the fact that it is a textbook for trade schools and a guide to the growing generation of gauger mechanics, it dedicates a mere 6 pages to the problem of repairing slide gauges, micrometers, and extensometers.

In 1951 the same press issued the book of a mechanic instrument maker V. I. Cherkashin "Advanced methods in gauge work." Both the first and the second enlarged editions deal too briefly with the repair and adjustment of universal gauges.

A. M. Chugunov's pamphlet "Gauge-making craftsmanship" issued by the same source in 1952 does not contain any information on the repair of measuring instruments; it only mentions the making and repair of setting gauges for screw micrometers.

A similar superficial reference is made on the repairs of measuring instruments in the book by B. A. Alekseev and A. I. Rosin entitled "Instrument-making art" (Mashgiz, 1952).

In 1954 the Trudrezervizdat issued N. P. Sobolev's book "Instrument and gauge making." The very title of the book, makes one expect to find in it the clarification of some of the "obscure" problems and gaps in the art of repairing universal gauges. The author of book, however, does not provide any new information as compared with the above-mentioned A. I. Rosin's book, as if in the six years which elapsed since the issue of that book nothing had changed in our instrument-making industry. Nothing is said in the book about the new improved methods of manufacturing and repairing measuring instruments, on the improvement and mechanization of repairs. Moreover, N. P. Sobolev's book advocates old outworn methods and techniques and described old, prewar measuring instruments whose, production has been discontinued.

In P. P. Zaretskii and K. S. Kharchenko's book "Gauger-mechanic," issued by the Mashgiz press, only 5 pages deal with repair and adjustment of measuring equipment.

The useful book on "Repairs and adjustment of measuring equipment," by B. V. Turkin issued by the same press in 1956 suffers from excessive condensation and is therefore incomplete and one-sided.

The problem of producing a textbook on the repair and adjustment of measuring instruments is still very pressing. The manufacturing plants as a rule make no spares. Instruments and gauges often fail for the lack of some insignificant component which is worn or has become defective. The components are repaired in a handicraft manner. And all this is due to the fact that the above books (whose list could be greatly increased) deal with the question of repair and adjustment of measuring instruments in a mean and bitty manner unrelated to the requirements and needs of modern production.

It is necessary for the leading scientists and engineers specializing in measuring instruments and other means of measurement to compile an exhaustive textbook on the basis of the long experience of the leading plants and mechanic instrument makers, a textbook which should become an indispensable guide to all the workers connected with the repair and adjustment of measuring instruments and gauges.

INFORMATION

CONFERENCE ON AUTOMATIC CONTROL AND METHODS OF ELECTRICAL MEASUREMENT

A. M. Ilyukovich
Translated from Izmeritel'naya Tekhnika, No. 3, pp. 57-58, March, 1960

In October, 1959, a conference was held in Novosibirsk on automatic control and methods of electrical measurement, organized by the Institute of Automatics and Electrometry (IAE) of the Siberian Section of the Academy of Sciences of the USSR. About 70 reports were made to the conference, and 375 representatives of 114 organizations participated in its work.

In a report of Candidate in Technical Science (C.T.S.) K. P. Shirokov (VNIIM) information was given on the activity of TK 24 MEK, studying electrical and magnetic units and values of TK 25 MEK, studying alphabetical designations and signs, and participation in this activity of the USSR.

P. P. Ornatskii, C. T. S. (Kiev Polytechnical Institute) presented a report on the International Conference on Measurement Engineering, held in Budapest in 1958. He dwelt in detail on the over-all state of instrument manufacture and the production of the individual instrument-producing factories in Hungary and Czechoslovakia.

Many of the reports were in connection with problems of automatic control and the automation of productive processes. In a report of B. S. Sinitsyn, C. T. S. (Novosibirsk Institute of Electrical Engineering), the dynamic errors of automatic control systems were considered. It was shown that in many cases the values of the dynamic errors exceed those of the static errors. Consideration was given to the indefinite character of changes in measureable values and disturbing influences in considering them as random functions of time. The report of M. P. Tsalenko, C. T. S. and V. O. Ulina C. T. S. (IAE) gave a comparison of the methods of mathematical processing of information by means of a matrix grid, giving examples of the use of grids for the statistical processing of experimental data. K. B. Karandeev, Corresponding Member of the Academy of Sciences of the USSR, F. B. Grinevich, C. T. S., V. P. Shchul'ts, C. T. S. and T. N. Mantush, C. T. S., presented the conference with reports on the ways and possibilities of automatic rejection of condensers in the process of their production. The report included a review of the general principles of construction of arrangements of that type, possible variations in the programming of the arrangement, methods of fixing the areas and limits of permissible values, and the productivity of various arrangements. Yu. V. Grachev and Z. B. El'yashevich (Azerbaidzhan Institute of Petroleum and Chemistry) reported on automatic devices for controlling the direction of oil-well shafts, axial pressure on the bit, the temperature of the well, etc. The reporters presented the characteristics and parameters of telemetrical conduits connected by strong cables to sunken electrical motors in work of the conduits in the range up to 100 kilocycles.

Automatic digital computers occupied a special place in the work of the conference. V. M. Shlyandin, C. T. S., (Penza Polytechnical Institute) reviewed in his report the general principles of construction of electrically measuring digital computers and a classification of them, gave examples of compensating diagrams for digital computers of dynamic and static equilibration, and compared these devices. N. V. Kirianaki discussed the multilimit automatic digital voltampere-meter developed in the L'vov Polytechnical Institute. The compensating diagram of V. S. Umantsev was chosen as the measuring scheme of the device. The reading of the indications is in four units. The limits of measurement of voltage are from 10 millivolts to 100 volts, of current from one milliamperes to ten amperes. The setting of the working current was done automatically on a standard cell and there is automatic compensation for the effect of temperature on the emf of the standard cell. E. I. Tenyakov reported on a digital-computer equipped automatic, direct-current compensator developed in the Novocherkassk Polytechnical Institute. The apparatus assures automatic measurement of direct current in the range from 0.1 to 1000 volts with

an error of 0.05%. The maximum rate is 20 measurements per minute. V. V. Kovalevskaya, C. T. S., and B. Z. Belen'skii (Institute of Electromechanics of the Academy of Sciences of the USSR) reported on a digital phasemeter with direct graduation of the scale in degrees, based on the transformation of the phase shift into a number of impulses. The device measures the mean value of the angle of the phase shift during several periods of alternating current. M. P. Tsapenko, C. T. S., A. A. Aref'ev, B. V. Karpyuk, A. N. Kasperovich and N. A. Khmelevskii (IAE) presented a report to the conference entitled, "A numerical electronic multiflow millivoltmeter," in which they reviewed the basic assemblies of an arrangement for comparing and forming a level compensating voltage, a zero element and a velocity selector. D. I. Malov told of two numerical ohmmeters developed in the Novocherkassk Polytechnical Institute. The first is based on a system of a multi-range six-armed bridge, the second on a system of a multirange four-armed bridge; the ranges of the measurements were 0.001-10 ohms and 100-100,000 ohms respectively; the basic errors 0.1-0.05% and 0.05% respectively; the times of one measurement three and two seconds. V. A. Ivantsov (Novocherkassk Polytechnical Institute) presented a report devoted to the measuring elements of automatic devices. The basis of the automatic measuring organ is the principle of amplification of direct current by means of modulation-amplification-demodulation. A vibrapack is used as a modulator. The pulsing signal is amplified by a multicascade alternating current amplifier with a large amplification coefficient. Demodulation is accomplished with an electronic phase-sensitive cascade charged on a fully polarized relay. A. M. Melik-Shakhnazarov, C. T. S., and I. L. Shain (Azerbaidzhan Institute of Petroleum and Chemistry) presented a report entitled, "Automatic rectangular-coordinate compensators for alternating current and their use for the measurement of impedances." Such compensators can be of either astatistic or statistic type. Study of these compensators as objects of automatic control permits the establishment of criteria for their efficient calculation. The use of automatic compensators for the measurement of impedances and conductances in a series of cases gives advantages over measuring equipment of the bridge type. L. Ya. Mizyuk, C. T. S. (IAE), in a report, "Alternating-current indicators," gave their classification and dependence on feasible functions (amplitudinal, differential, phase, componential, vectorial, frequency, impulse) and reviewed the use of indicators in automatic compensators and the like. Especially great possibilities are shown by indicators based on electronic and semiconductor circuits, which assure a reaction on various parameters of alternating current.

A whole series of reports was devoted to the question of electrical measurement of nonelectric values. V. I. Roskin (Ufimsk petroleum reprocessing factory) reviewed deficiencies in existing automatic analytical devices and spoke of the modernization carried out in the factory of equipment for measurement of aluminum sulfate concentration in aqueous solution. Another representative of that factory, S. G. Prokopok, told of a newly developed VA-56 device for determining the viscosity of solid petroleum products with an error not exceeding ±1%, and of an automatic recorder of salt content in petroleum. The apparatus is accurate within ±2%. G. S. Chernorutskii, C. T. S., (Chelyabinsk Polytechnical Institute) told of systems for the measurement of the twisting angle and of a system for measuring moments on the operating shaft of an experimental machine intended for the drilling of explosive borings in the opening-up of mines and oil wells. The report explained the structural peculiarities of the system of measurement and the results of its trial, and also described the principles of measurement of extremely small deflection angles of an indicating transmitter of the selsyn type. In another report he told of a compensatory system of measurement for measurement of the rate of feed of an instrument of an experimental machine for drilling explosive charges. B. I. Puchkin (VNIIM), in a report entitled "Some problems in the investigation and improvement of attached tensotransmitters," explained the present state of measurement with tensotransmitters and the basic characteristics of experimental models of tensotransmitters with an increased signal in comparison with existing models. He also reviewed the extension of the possibility of using tensotransmitters in automatic control systems if the output signal of the tensotransmitter is raised. The need for standardizing attached tensotransmitters was pointed out and the starting materials for its development were given.

A large group of reports dealt with problems connected with devices of immediate value. A. Ya. Shramkova, C. T. S., (L'vov Polytechnical Institute) presented a report, "Some problems of the theory of electrical measuring devices of immediate value," in which she reviewed the connection between indicational error of a device and the errors of measuring circuits and a measuring mechanism in the case of nonlinear dependence between the reading of the equipment and the measurable value. The speaker analyzed in detail the sources of error in equipment. A. Ya. Beznikovich, C. T. S., and D. I. Zorina, C. T. S., (VNIIM), reviewed direct-indicating thermoelectric equipment on which the temperature errors and also the fluctuation of indications inherent in equipment of that type are eliminated by the introduction of preliminary preparation for the measurements. This preparation includes regulating the circuit elements to obtain an earlier definite reading of the equipment measuring the

thermoelectromotive force at a set unchanged current through the heater of the heat transformer. A. V. Lashas (Kaunas Polytechnical Institute) in a report entitled "Some methods of damping high-speed recorders," reviewed two methods of damping: by introduction into an electronic amplifier of a positive feedback along the current of the recorder, and the introduction of a correcting circuit connected to the recorder in parallel with clamps and consisting of a resistance, inductive reactance and capacitive reactance connected in series.

A group of reports was concerned with calibrated measurement standards and measurements with high accuracy. V.P. Shigorin (VNIIM) presented a report entitled, "Bridge for the comparison of calibrations and standards of resistance within the limits of 0.001 to 100,000 ohms," The greatest relative error of the method developed, taking temperature into consideration, was estimated to be the following values: 0.00001-0.00005% in comparing 0.1-1000 ohm coils; 0.00005-0.0001% in comparing 0.01, 0.001, 10,000 and 100,000 ohm coils; 0.0001-0.001% in the measurement of resistances not equal to 10^n ohms (where n is a whole number) within the limits of 0.001 to 100,000 phms. M. A. Bykov, C. T. S., (VNIIK), in a report entitled "The development of apparatus for precise measurement of the loss angle of condensers and the constant time of multiohm resistances," told of UPPV-1 equipment which assures the measurement of loss angles with an accuracy of $(1-2)\cdot 10^{-5}$ rad and of constant times with an accuracy up to $(1-2)\cdot 10^{-9}$ seconds in a frequency range from 40 cycles to 20-50 kilocy les.

A few reports dealt with various questions about the technique of electrical measurements. In a report of Professor M. I. Levin (MÉI) on the properties of phase-sensitive circuits with a series-parallel network there was shown, in particular, the possibility of a selection of parameters of the network in which the indications of the meter depend little on the resistance of its winding, and some possible fields of application of such networks were reviewed. A report by Professor M. I. Levin and R. M. Demidova dealt with the use of alternating current potentiometers for higher frequencies. It was shown that the currents caused by the capacitances between the windings of separative transformers can exert considerable effect on the accuracy of measurements. They suggested a method of developing and estimating the values of these currents and a method of full compensation for their effect by means of special equipment. I. F. Klistorina, C. T. S., and N. V. Degtyarik (IAE) reviewed the thermistor bridge as an indicator of the voltage deviation of alternating current. A bridge circuit was obtained in which the temperature effect was brought down to 0.1-0.2% per 10°C in the temperature range from +15 to +35°C. A report of V. S. Popov, C. T. S., (Institute of Electromechanics of the Academy of Sciences of the USSR), entitled "Statistical transformers for precise measurement of capacities," was presented to the conference. This report gives the possibility of measuring capacities with an accuracy of some hundredths of a percent, which permits using it for checking standard wattmeters in a broad range of frequencies and also of making an accurate measurement of capacity at low power factors.

The conference adopted a resolution which mentioned the considerable growth in the number of papers on automatic control and methods of electrical measurement.

INTERNATIONAL CONFERENCE ON THE MEASUREMENT OF LIQUID DISCHARGE IN OPEN CHANNELS AND WATERWAYS

S. B. Bulatov and N. M. Karelin
Translated from Izmeritel'naya Tekhnika, No. 3, pp. 59-61, March, 1960

The second Conference of Subcommittee ISO/TK 30/PK on "The measurement of liquid discharge in open channels and waterways" of Technical Committee ISO/TK30 on "The measurement of liquid discharge" of the International Standardization Organization (ISO) [1] has been held at the British Institute of Standards (London).

The meeting was attended by delegates from the member-countries of the Subcommittee: : the USSR, England, Belgium, East Germany, West Germany, India, the U.S.A., France, the chairman of the Subcommittee (India) and the chairmen of the International Commission on Irrigation and Drainage, the International Association

for Hydraulic Research and the International Electrical Engineering Commission (MÉK).

Work in the USSR in preparation for the meeting was performed by the commission on measurement of liquid discharge in pipelines, open channels and waterways in the All-Union Scientific Research Institute of the Committee of Standards, Measures and Measuring Equipment [1].

The commission has composed remarks on the following internationally recommended drafts:

1) the revised draft of proposals for measurement of the liquid discharge of water in open channels and waterways by the area-rate method;

2) the revised draft of proposals for measurement of the discharge of water with the use of spillways and troughs;

3) the revised draft of proposals for a glossary of terms used in the measurement of the discharge of liquid in open channels and waterways.

The work of the meeting proceeded to plenary sessions of the Subcommittee and sessions of its working groups: Group 1: "Area-rate methods," Group 2: "Spillways and troughs," Group 3: "Dictionary of terms," and Group 4: "Method of Displacement," a group created at the meeting.

The head of the Indian delegation, Kanvar Sein, was elected chairman of the meeting.

At the sessions of Group 1 (Dr. Spencer of Britain presiding) the draft of proposals for the measurement of water discharge in open channels and waterways by the area-rate method was reviewed and the decisions of the member-countries of the Subcommittee were discussed.

The basic questions introduced into the discussion by the USSR and in the supplementary remarks had to do with instructions for the selection of the line; measurements of the width of rivers by use of cables; methods of measuring the depth of a river in relation to the width of the river and the profile of the hydrometric line; methods of determining the average velocities of the current toward the hydrometric line, and methods of measuring velocities on the verticals in ordinary and complex conditions (the number of velocity verticals, six-point and three-point methods, a method of applying detailed, basic and abridged ways of measuring discharge); the need for providing full instructions to assure the possibility of practical reproduction of the method of "distributed rates," in which a difference in the value of adjacent rates on a vertical will not exceed 20% of the greater rate; methods of using an integration method to measure the average velocities on the vertical; factors affecting the accuracy of readings of a hydrometric dial and instructions for making measurements under winter conditions; making the method of plotting a curve of elementary discharges more precise; the necessity of working-up the maximum errors both in measurements and in the calculations of discharge by methods adopted in the draft of proposals; the expediency of establishing and eliminating a series of terms to bring the terminology of documents into full correspondence with the respective sections of the glossary of terms worked up by Group 1.

The remarks of the member-countries and the results of the discussion were considered the basis for setting up an "intermediate document" which will be referred by Group 1 to the next conference of the Subcommittee. This document extends only to "separate measurement of discharge" and does not extend to the question of the "level-discharge" ratio. The Subcommittee decided that the problem of working up the document establishing the "level-discharge" ratio is not of primary importance but should be included in the future work of Group 1.

It was decided to include the remark that the document does not extend to the measurement of discharge made to determine the efficiency of pipelines, since there exist the recommendations of MÉK, document TK-4, for this purpose.

Group 1 devoted basic attention to the question of errors in the measurement of discharge. The need was pointed out for developing a section containing data relating to the evaluation of discrete errors in the measurement of the width, depth, velocity, etc. and to the method of determining the maximum error of measurement of discharge. Work on this problem was recommended [2]. The adopted resolution obligated the members of Group 1 to present a series of standard measurements in rivers and channels which could be used for the analysis of the accuracy of methods of calculating discharge included in the draft of proposals.

On the question of measuring the profile of the hydrometric line, it was decided that the distance between measured verticals should not be more than 1/15 or 1/20 (in an uneven profile) of the width of the stream.

The suggestion of the French delegation regarding the use of a control hydrometric dial at a fixed point in the current, and the Soviet proposal to include six-point and three-point methods for complex conditions were accepted as methods of measuring the rate.

The German delegates had worked up a more precise revision of the item relating to the integration method. There was no objection to the proposal of the French delegation to supplement the document with the "horizontal plane" method, which is convenient for use in channels. The French delegation assumed the obligation of elaborating the corresponding item in the document. As an alternative, a method of introducing corrections for change in level, proposed by the delegation of the U. S. A., was included.

The review of questions on which it had not been possible to come to a decision was postponed.

Among the more important questions regarding the document were:

1) a further review of document MEK/TK 4; 2) analysis of a large number of standard measurements of discharge for evaluation of error; 3) the composition of a draft of the section on errors; 4) the composition of a more fundamental introduction to the document; 5) solution of the question of the possibility of establishing the maximum admissible wind velocity and of normalizing floating measurements of discharge; 6) checking the glossary of terms being prepared by Group 3; 7) the composition of items or proposals on the question of introducing corrections for sag and stretch of the line in measurement of the width of a stream and of introducing corrections for deviation of the line in measurement of depths and points of measurement of the velocities on the verticals (a document of the U. S. A. [3] on this problem was recommended for study); 8) review of the problem of accuracy of measurement in the level and the effect of swinging of the level during measurement of the discharge (the introduction of corrections both for height and for the rate).

Group 1 noted the following problems which require further study for solution of the question of possible standardization: 1) measurement of discharge in rivers subject to ebb and flow: 2) general questions of the measurement of pulsing discharges; 3) a method of measuring the discharge on a slope (the English delegation stated that it will prepare a report later; 4) the working up of additional requirements whose fulfillment is necessary for establishment of the "level-discharge" ratio on the basis of discrete measurements of discharge.

At the sessions of Group 2 (Professor Schlag of Belgium presiding) the draft of proposals for the measurement of water discharge in open channels and waterways by using spillways and troughs was not reviewed point by point and was only accepted as the basis of discussion in connection with the general opinion of the participants in the session that the document was impractical, and also in connection with the conclusions of the USSR, East Germany and France, the remarks of Hungary and Italy and the suggestion by England of the necessity of making major changes in the body of the document adopted by the meeting of 1956.

The major changes in the document coming from the USSR agreed with the opinion of Group 2. It was noted that only a scheme was in the presented form of the document, and that it did not contain the requirements and all the necessary facts on spillways and troughs which would assure the possibility of reproducing these hydrometric installations and obtaining comparable results of measurement. The Soviet delegation proposed excluding Venturi tubes from the document, since they are included in the draft of document ISO/TK 30 on measurement of liquid discharge in pipelines by means of a diaphragm, nozzles and Venturi tubes.

Group 2 left in the document only the most thoroughly investigated equipment, on which the calculated values of the coefficients, limits of application, the conditions of arrangement and the permissible errors could be established.

Group 2 decided not to include hydrometric equipment of the submerged type, but noted that this equipment should be taken into consideration in composing the document.

Venturi tubes, hydrometric probes and a series of spillways (circular, proportional, longitudinal and diagonal) were included.

The following body of the document was established as a result of the discussion:

A. Hydrometric arrangements of the short type

Spillways with sharp edges:

a) rectangular without lateral compression,

b) rectangular with lateral compression,

c) triangular,

d) trapezoid,

e) combined.

B. Hydrometric arrangements of the long type

Structures with erect wave:

a) with bottom compression,

b) with lateral compression,

c) with bottom and lateral compression, including the rectangular and other cross-sections of simple geometric forms.

Group 2 decided that the recommendations of the document should indicate the possibility of using any of the enumerated hydrometric arrangements for the measurement of discharge both in artificial channels and in natural streams. In the latter case the specific conditions of the arrangement and the limits of application should be stipulated. It was especially noted that, for the purpose of expanding the work in a new direction, comparatively large rivers should be studied.

The working group recommended basing future work on a general equation. As regards the intermediate document, which should be distributed to all members of Group 2 at the meeting of the Subcommittee, two alternative methods of constructing discharge formulas were recommended:

a) the usual empirical formula with indication of the numerical values of the coefficients and limits of application,

b) a general equation [4] and factors for the rate of approach [5, 6].

At the sessions of Group 3 (Tibessar of Belgium presiding) the basic part of the reviewed draft of proposals for a glossary of terms used in liquid measurement in open channels and waterways was gone over item by item, as were the conclusions from the USSR and Germany, the remarks of Professor Marzolo (Italy), and England's suggestion for the improvement of the glossary given to the delegates at the meeting.

The USSR delegation agreed that at the present time basic attention must be given to the glossary of terms and definitions in the English language, but noted that the work should be done in such a way that the glossary can be issued in all the official languages of the ISO. In addition, the delegation pointed out the expediency of including only those terms which are used and will be used in the text of documents worked up by the Subcommittee.

Group 3 decided that the work of creating a glossary of terms in the English language should be completed first of all, so that later on identical texts in the Russian and French languages can be prepared.

In connection with the fact that in some cases terms in the Russian and French languages will be only approximate equivalents of English terms, Group 3 decided that basic attention must be given to the precise definition of the terms in the English language.

At the sessions of Group 4 (Remenier of France presiding) were reviewed French proposal "Methods of displacement" and French code No. 4a (2nd edition), published by the Society of Hydrotechnicians of France.

Group 4 adopted a resolution to proceed to the development of the project of proposals for a method of displacement for measuring discharge in both rivers and artificial channels.

In accordance with the resolution that the document should contain the requirements for chemical, apparatus, and the technique of measurement and of introducing a solution into a stream, and for analytical methods, the following composition of the document was established: 0. Introduction. 1. Purpose. 2. Principles of the

displacement method (methods of direct and relative measurement of concentration). 3. Characteristics of solutions. 4. The selection of measuring regions and lines of direction. 5. Preliminary measurements. 6. Procedure (preparation of a concentrated solution, introduction of the solution, measurement of the rate of introduction, taking of the sample). 7. Chemicals and methods of analysis. 8. Errors.

At the plenary sessions of the conference the main decisions of the working groups were confirmed and the direction of their further activity was given.

At the present time the working groups, preparing for the third conference of the Subcommittee at the end of 1960, are revising the recommended projects in order to have them in thoroughly finished form.

LITERATURE CITED

[1] S. B. Bulatov and N. M. Karelin, Izmeritel'naya Tekhnika 6 (1956).

[2] K. B. Young, A comparative Study of Mean-Section and Mid-Section Methods for Computation of Discharge Measurements, Washington, D. C., U. S. Department of the Interior, Water Resources Division, 1950.

[3] D. M. Corbett and others, Stream Gaging Procedure. Water Supply Paper 888, Washington, D. C., U. S. Department of the Interior, Geological Survey, 1945.

[4] F. V. A. Engel and W. Stainsby, Weirs for Flow Measurement in Open Channels, Reprint of series of articles published in Water and Water Engineering, April to August 1958 inclusive, Parts 1-5.

[5] F. V. A. Engel and W. Stainsby, Velocity-of-approach factors in unified weir equations. Proceedings of the Institution of Civil Engineers, February, 1958.

[6] F. V. A. Engel and W. Stainsby, Correspondence on a paper published in the Proceedings, February, 1958. Proceedings of the Institution of Civil Engineers, August, 1958.

N. F. RYMAR'

On his 60th Birthday and After 45 Years of Production) Engineering and Scientific Research Activity

Translated from Izmeritel'naya Tekhnika, No. 3, p. 61, March, 1960

In March, 1960 sixty years have passed since the birth of Nikolai Fedorovich Rymar', including 45 years of production, engineering and scientific research activity.

Rymar' began working as a 15-year old youth, starting as a locksmith.

He served in the cavalry of the Red Army during the years of the Civil War.

After demobilization he worked from 1922 to 1929 as a locksmith, an electrician, a welder, and without discontinuing work,completed the course of studies at the Kiev Polytechnical Institute.

From 1929 to 1931 Rymar' worked as a design engineer at the Tochpribor factory (Kiev), developing and manufacturing manometers, liquid-measuring devices, gasometers and other measuring devices.

From 1931 to 1940 he worked as a design engineer in the Bureau of Interchangeability, concerned with problems in the construction of unique measuring machines and automatic controls.

From 1940 to 1953 Rymar' was director of the sector of scientific research work of the committee on matters of measures and measuring devices in the Council of Ministers of the USSR. He made a large contribution to the creation and administration of the state technical documentation and of normatives for ways and means of measurement.

The design work of N. F. Rymar' in the creation of new, progressive means of measurement, his well-known scholarly and published works are used everywhere in the machine and equipment-construction industry and have won their author great esteem and gratitude in the field of equipment construction. It must be mentioned that the first published work devoted to problems in the automation of the control of dimensional parameters, "Automatic Control of the Dimensions of Components in Machine Construction" [in Russian] (1940) was from the pen of N. F. Rymar'. A series of his works has been published in the Chinese Peoples' Republic and in the Hungarian Peoples' Republic.

In 1950, after taking part in the development of designs and the installation of automatic equipment for the first automatic automobile piston factory, N. F. Rymar' was awarded the title of laureate of the Stalin Prize of the first degree.

In 1953, N. F. Rymar' transferred to pedagogical work in the Department of Metrology and Equipment Construction of the Moscow Mechanical and Instrumental Institute.

With a rich and varied experience in production, design-engineering and scientific research work, Rymar' lovingly gives all his knowledge and experience to young equipment-building specialists, with whom he enjoys deserved authority.

Rymar' takes an active part in the work of this journal.

One of the originators in the installation of automatic control of dimensions in machine construction, the author of series of new designs of automatic equipment and of many published works, N. F. Rymar' has been awarded three decorations by the government.

We wish him health, strength and further creative success.

IN THE COMMITTEE OF STANDARDS, MEASURES AND MEASURING INSTRUMENTS

CHANGES IN INSTRUCTIONS FOR VERIFICATION OF INSTRUMENTS FOR MEASURING TEMPERATURE

N. M. Staroverov

Translated from Izmeritel'naya Tekhnika, No. 3, pp. 62-64, March, 1960

The Committee of Standards, Measures and Measuring Instruments in the Council of Ministers of the USSR has adopted and put into effect, as of May 1, 1960, changes in Instructions 164-54, 166-54 and 169-54 included in the collection, "Instruments for Measuring Temperature and their Verification."

The instructions 164-54 on the verification of pyrometric voltmeters, point one, of the last item of Table 37 is eliminated and point one is completed by a text with the following content: "Conditional markings of graduation and the limits of measurement of millivoltmeters working in assembly with the telescope of radiation pyrometers are determined by the conditions on the radiation pyrometers."

The second paragraph of item 9 and the footnote to it are deleted, as in the comment on item 10.

Item 32a is stated in the following revision:

"32a. Measurement of the voltage on the clamps of the millivoltmeter (at $R_{int} = 0$) in setting the indicator on the numbered markings of the scale and in comparison of the results of measurement with the graduated table of the millivoltmeter of a given calibration. This method is used to check millivoltmeters intended for work in ensemble with radiation pyrometers of type RP (see Supplement 12) and type RAPIR. In the case of issuance of instruments by maintenance shops, the resistance of the millivoltmeter must also be checked by the method set forth in item 27 of these instructions. In millivoltmeters of calibration RP the resistance must be 170 ± 1 ohms and 200 ± 1 ohms in millivoltmeters of type RAPIR.

Supplement 13, "Calibration data of the scale of millivoltmeters MPB-46, SG, ÉRM-47 of class 1.5 for radiation pyrometer of type RP," is withdrawn and the table of Supplement 12 substituted.

In instruction 166-54 on the verification of automatic potentiometers, modifications are inserted which take into account the requirements of GOST 7164-58, "Potentiometers and balanced automatic electronic bridges." (GOST – All-Union State Standard.)

Basic changes have been introduced in the section of the instructions entitled "Specifications," item 2 being stated in the following revision:

"2. The fundamental error of automatic potentiometers intended for work in ensemble with thermocouples and radiation pyrometers must correspond to the degree of accuracy indicated on the instrument and must not exceed, on all the marks, the values given in Table 1.

The basic error is expressed:

a) for instruments with a single scale – in percentages of the upper limit of measurement;

b) for instruments with a double scale – in percentages of the sum of the absolute values of the upper and lower limits of measurement.

In the determination of the basic error the limits of measurement must be expressed in units of voltage.

The translation of the calibration scale of potentiometers into units of corresponding voltages is done, for instruments destined for work in ensemble with thermocouples, according to the tables of Supplements 5-8, and

Supplement 12

Calibration Data of the Scale of Millivoltmeters for Radiation Pyrometer, Type RP

Temperature in °C	Voltage in mv of corresponding scale mark	Temperature in °C	Voltage in mv of corresponding scale mark
1800	18.09	1360	6.22
1780	17.38	1340	5.83
1760	16.70	1320	5.47
1740	16.04	1300	5.13
1720	15.40	1280	4.81
1700	14.77	1260	4.50
1680	14.15	1240	4.20
1660	13.56	1220	3.91
1640	12.98	1200	3.65
1620	12.41	1180	3.40
1600	11.85	1160	3.17
1580	11.31	1140	2.94
1560	10.76	1120	2.73
1540	10.23	1100	2.53
1520	9.72	1080	2.33
1500	9.23	1060	2.15
1480	8.76	1040	1.97
1460	8.30	1020	1.81
1440	7.85	1000	1.65
1420	7.41	900	0.99
1400	6.99	Red line	0.00
1380	6.61		

Comment: For millivoltmeters of class 1.5 a deviation of ± 0.27 kv from the values given in the table is allowed, and ± 0.18 kv for millivoltmeters of class 1.0.

TABLE 1

Class of accuracy	Basic error
0.2	± 0.2
0.5	± 0.5
1.0	± 1.0

TABLE 2

Class of accuracy (according to readings)	Basic recording error (%) of equipment with width of field of recording	
	200 mm or more	less than 200 mm
0.2	± 0.5	± 0.5
0.5	± 0.5	± 1.0
1.0	± 1.0	± 1.0

for instruments intended for work with radiation pyrometers according to the tables corresponding to the calibrations given in the installation and operating instructions. Calibration tables for PR radiation pyrometers are given in Supplement 14."

Item 4 is replaced by the following:

"4. The basic recording error in self-recording equipment must at all marks of the scale not exceed the values given in Table 2.

The basic recording error is expressed in the same way as the error in reading (item 2)."

Item 27 is stated in the following revision:

"Damping of the movable part of instruments must be such that the indicator is in place after not more than three half-swings for indicating instruments, and two-half-swings for self-recording instruments."

In addition, several changes in points 5, 6, 8, 9, 15, 16, 17, 19, and 26 were introduced into the "Specifications" section in accordance with GOST 7164-58. They related to specifications demanded only for instruments released from production (basically in control experiments). Item 33 was deleted.

In the "Verification" section (item 44) the delay period before checking of instruments was changed. The instrument is maintained at nominal voltage for two hours; the initial warming-up period can be reduced to the point where further warming-up of instrument does not cause a change of reading amounting to more than 20% of the basic error.

Item 46 is supplemented by the conditions under which the basic error and the variation of an instrument are determined, namely:

a) the ambient air temperature must be + 20 ± 5°C;

b) the voltage of the power supply must differ from the normal by not more than ± 3%, and the frequency by not more than ± 1%;

c) external magnetic fields apart from the geomagnetic field must practically not exist;

d) checking of instruments with temperature compensation must be done after the thermal state of the compensatory resistances has been established (that is, their temperature must change not more than 0.5°C in the course of 30 minutes);

e) calibrating instruments used to determine the basic error must assure measurement of voltage with an error not exceeding 20% of the basic error of the instrument being verified;

f) in determining the recording error in a self-recording instrument in relative humidity of the air differing from 60%, the effect of humidity on the dimensions of the diagrammatic paper must be taken into consideration."

The table of Supplement 14 has also been changed on the basis of the work that has been carried out.

SUPPLEMENT 14

Calibration Data of the Scale of Automatic Potentiometer for Radiation Pyrometer, Type RP

Temperature °C	Voltage, mv corresponding given scale mark	Temperature, °C	Voltage, mv corresponding given scale mark	Temperature °C	Voltage, mv corresponding given scale mark
1800	18.62				
1790	18.25	1520	10.01	1250	4.47
1780	17.89	1510	9.75	1240	4.32
1770	17.54	1500	9.50	1230	4.17
1760	17.19	1490	9.26	1220	4.03
1750	16.89	1480	9.02	1210	3.89
1740	16.51	1470	8.78	1200	3.76
1730	16.18	1460	8.54	1190	3.63
1720	15.85	1450	8.31	1180	3.50
1710	15.52	1440	8.08	1170	3.38
1700	15.20	1430	7.85	1160	3.26
1690	15.88	1420	7.63	1150	3.14
1680	14.57	1410	7.41	1140	3.03
1670	14.26	1400	7.20	1130	2.92
1660	13.96	1390	7.00	1120	2.81
1650	13.66	1380	6.80	1110	2.70
1640	13.36	1370	6.60	1100	2.60
1630	13.07	1360	6.40	1090	2.50
1620	12.78	1350	6.20	1080	2.40
1610	12.49	1340	6.00	1070	2.30
1600	12.20	1330	5.81	1060	2.21
1590	11.92	1320	5.63	1050	2.12
1580	11.64	1310	5.45	1040	2.03
1570	11.36	1300	5.28	1030	1.94
1560	11.08	1290	5.11	1020	1.86
1550	10.80	1280	4.95	1010	1.78
1540	10.53	1270	4.79	1000	1.70
1530	10.27	1260	4.63	900	1.02

Changes in instruction 169-54 relating to verification of technical radiation pyrometers take into account specifications GOST-6923-54, "Radiation Pyrometers and the data of results of tests of telescopes for radiation pyrometers of type RP.

In the section of the instructions headed "Specifications," items 1, 2, and 3 are stated in a new revision, namely:

"1. The limits of measurement of pyrometers being verified and the sighting index of the telescope of a pyrometer are standardized by the technical conditions of the producing factory and must be indicated on the shield of the telescope.

The sighting index is expressed by the ratio of the diameter of the circle inscribed in the contour of the radiator to the distance from the source to the lens of the telescope.

TABLE 1

Limits of measurement in °C	Basic error in °C, not more than
From 600 to 1200	±12
From 700 to 1400	±14
From 900 to 1800	±18
From 1100 to 2000	±22

The certificate of the producing factory, attached to the telescope must indicate, depending on the distance (beginning with 500 mm or more) from the radiator to the telescope, the values of the sighting indices at which the basic error of the telescope does not exceed the values given in Table 1.

2. The basic error of readings of radiation pyrometer telescopes must not exceed the values given in Table 1.

The basic error must not exceed the indicated values incompliance with the following conditions:

a) a temperature of the telescope equal to 20 ± 2°C;

b) sighting with maintenance of the indices established for a given telescope in accordance with item 1.

The telescope of a pyrometer must operate at ambient air temperatures from 0 to 100°C, and the panel from 0 to 50°C.

3. Change in the readings of a radiation pyrometer caused by change in the temperature of the body of the telescope must not exceed the values given in Table 2.

Item 4 is deleted; in point 8 the words "10 meg" are replaced by the words "20 meg" and item 10 is stated in the following revision:

TABLE 2

Change in temperature of body of telescope in °C	Change of pyrometer readings in °C
From 20 to ±40°	±3.5
From 20 to ±60°	±8
From 20 to ±80°	±13
From 20 to ±100°	±18

"10. The following must be indicated on the pyrometer telescope: a conventional designation of the pyrometer type, the sighting index, a conventional designation of the calibration and limit of measurement, the serial number of the pyrometer, the year of issue and a plus sign on the positive clamp of the telescope."

In the section of the instructions headed "Verification, operation and formulating the results" item 14 is stated in the following revision:

"14. Verification of the telescopes of radiation pyrometers, and measuring instruments working in ensemble with them, must be made separately. The telescope is verified by the method given below, and the measuring instruments are verified in accordance with the instructions for verifying pyrometric millivoltmeters and automatic potentiometers. In verifying technical telescopes separately from the measuring instrument the connecting panel must be used without fail."

In item 26m the reference to Supplement 15 is deleted and the item is completed by a remark with the following content:

"The calibration tables for telescopes of type RAPIR are given in the instructions for assembly and use; the calibration table for telescope RP is given in Supplement 15."

SUPPLEMENT 15

Calibration Date for Radiation Pyrometer Telescopes, Type RP

Temperature °C	Calibration data, mv	Allowable deviation, mv	Temperature °C	Calibration data, mv	Allowable deviation, mv	Temperature °C	Calibration data, mv	Allowable deviation, mv	Temperature °C	Calibration data, mv	Allowable deviation, mv
900	1.02	±0.16	1120	2.81	±0.30	1380	6.78	±0.54	1600	12.20	±0.76
910	1.08	±0.16	1180	3.50	±0.35	1390	6.99	±0.54	1610	12.49	±0.78
920	1.14	±0.16	1190	3.63	±0.35	1400	7.20	±0.54	1620	12.78	±0.78
980	1.54	±0.22	1200	3.76	±0.35	1410	7.42	±0.57	1680	14.57	±0.84
990	1.62	±0.22	1210	3.89	±0.38	1420	7.64	±0.59	1690	14.88	±0.86
1000	1.70	±0.22	1220	4.03	±0.38	1480	9.02	±0.65	1700	15.20	±0.87
1010	1.78	±0.22	1280	4.95	±0.43	1490	9.26	±0.65	1710	15.52	±0.89
1020	1.86	±0.22	1290	5.11	±0.46	1500	9.50	±0.67	1720	15.85	±0.89
1080	2.40	±0.27	1300	5.28	±0.46	1510	9.75	±0.70	1780	17.89	±0.97
1090	2.50	±0.27	1310	5.45	±0.46	1520	10.01	±0.70	1790	18.25	±0.97
1100	2.60	±0.28	1320	5.63	±0.48	1580	11.64	±0.76	1800	18.62	±1.00
1110	2.70	±0.28				1590	11.92	±0.76			

CORRECTIONS

1. In "Rules 12-58 for the organization and carrying-out of verification of measures and measuring instruments and the control of the state of measuring technique, the observance of standards and technical conditions," (Moscow 1959, published December 25, 1958), an error occurred.

Location	Printed	Should be
Page 24, Supplement 1, No. p/p. 58, graph "Verification periods (no less often)."	Once per year	Once in five years

2. In a monograph on measuring technique, "The present state of the technique of measuring viscosity," Issue 10 (State Press for Standards, Moscow, 1959) only two authors were erroneously listed – L. P. Stepanov and N. A. Chesikov.

The authors of the monograph were G. A. Malyarov, L. P. Stepanov and N. A. Chesnikov.

NEW NORMATIVE DOCUMENTS FOR MEASURES AND MEASURING INSTRUMENTS, APPROVED BY THE COMMITTEE OF NEW STANDARDS

(Registered in January, 1960)

GOST 1032-60 Glass urometer and cylinder. Replaced GOST 1032-41.

GOST 9341-60 Glass laboratory sulfonators. Introduced for the first time.

GOST 3199-60 Gages for metric threading with diameters of 0.25 to 0.9 mm. Tolerances. Replaces GOST 3199-46.